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ORIGIN AND DEVELOPMENT OF LINT AND FUZZ IN COTTON*

By G. Seshadri Aiyangar, M.A., M.Sc., Assistant Cotton Specialist, Narasaraopet

(Received for publication on 14 May 1951)
(With Plates XII—XVII)

THE name 'Lint' is commonly used for the cotton hairs that can be separated from the seed by ginning. When the same is removed by the above process, the surface of the seed ranges from smooth, shining and devoid of any hairs as in Sea Island cotton (*Gossypium barbadense*, Linn.) to cover with a coating of dense short hairs as in Cambodia (*G. hirsutum*, Linn.). All suchfibres that are not ordinarily removable from the seed by ginning are popularly called Fuzz. The varieties that do not have fuzz on the seed coat are known as naked seeded types. The presence or absence of these two kinds of fibres, viz. lint and fuzz on the surface has been reservedly accepted by Watt [1907] as affording a satisfactory basis for scientific classification. The peculiarities observed in some of the wild species were deemed by him to be of undoubted specific, if not of subgeneric value. Balls [1915] observed that fuzz fibres had larger diameter than the lint and showed by using ammoniacal solution of copper-hydroxide that fuzz hairs produced fewer but more distinct lamellations than the lint fibres. A microscopical examination of the hairs revealed that those that are usually grouped under fuzz were found to be broad at the base with cytochrome in the cell while in the case of lint the base tapered sharply, and did not possess any cytochrome. In view of the above differences which were fundamental in nature, it was thought worthwhile to examine in detail, the two classes of hairs, especially from the point of view of their origin and development.

Previous literature

The previous workers [Watt, 1907, Turner 1929 ; Farr, 1931 ; Barrit, 1932 ; Sheffield, 1936 ; and Lang, 1938] have summarised the literature on the origin of the cotton hairs. Weiss [1867] was the first to classify the hairs and to declare that the hairs on the seed coat of cotton are unicellular in form and epidermal in origin. De Bary [1877] observed that while plant hairs could also be of subepidermal origin, the hairs on the seed coat of cotton were of epidermal origin only. Bowman [1881] pointed out in a text figure, that young cotton fibres had their origin in the second layer of cells beneath the cuticle. Subsequent workers agreed with De Bary. Regarding the time of production of the hairs, Balls [1915] stated that most of the cotton fibres were produced on the day of flowering only and that fertilization had no effect on the number of fibres produced. Turner [1929] and Gulati [1930] differed from the above view and concluded that additional crops

* Part of thesis submitted for M. Sc. degree of the Madras University.

of hairs were produced even after the day of flowering basing their conclusions on the observed differences in the number of hairs on the ovular coat on the date of flowering and later dates. This conclusion was confirmed by subsequent workers [Singh, 1931 ; Farr' 1931 and 1933 ; Ayyar and Aiyangar, 1933 and 1934 ; Sheffield, 1936 ; and Lang' 1938].

With regard to the origin of fuzz, Balls [1915] stated that it was similar to that of lint in all respects. All subsequent workers except Ayyar and Ayyangar [1933, 1934], Sheffield [1936] and Lang [1938] agreed with the above statement of Balls. Ayyar and Ayyangar [1933] stated that fuzz hairs differed from lint both in place and time of origin. Sheffield [1936] and Lang [1938] independently concluded that both fuzz and lint were of epidermal origin but believed that the later formed hairs invariably developed into fuzz.

TABLE I

The list of varieties examined

Variety	Species after H. and G.	Strain	Source of supply
(a) *Lint and Fuzzy:*			
Cambodia	*G. hirsutum*, Linn.	Coimbatore-2 (Co. 2)	Coimbatore.
Russian hisrutum	*G. hirsutum*, Linn.	9243	U.S.S.R.
Durango	do.		U.S.A.
Lonestar	do.		U.S.A.
Acala	do.		U.S.A.
Dharwar American	do.		Dharwar, Bombay presidency
Uppam	*G. herbaceum var. frutescens*, H. and G.		Coimbatore
Million Dollar	*G. arboreum var. neglectum forma bengalensis*, H. and G.		Punjab
Roesum	do.		Nagapur
(b) *Linted and Naked:*			
Ashmouni	*G. barbadense*, Linn.		Egypt
Sakel	do.		do.
Sea Island	do.		West Indies

TABLE I—*contd.*

The list of varieties examined—contd.

Variety	Species after H. and G.	Strain	Source of supply
Ishan	*G. barbadense Lem.*		Nigeria
Kidney	*G. barbadense, var. braziliense, L.*		do.
Moco	*G. hirsutum var. purpurascens, Poir*		Brazil
Bourbon	do.		Coimbatore
(c) *Lintless and fuzzy :*			
Punjab hairy lintless	*G. arboreum, var. neglectum forma bengalensis H. and G.*	(Mutant)	Lyallpur (Punjab)
Downy lintless	do.	do.	do.
Nandyal lintless	*G. arboreum var. neglectum forma indica H. and G.*	do.	do.
(d) *Wild types .*			
Davidsonii	*G. Davidsonii, Kell*		Trinidad
Stocksii	*G. Stocksii*, M. Mast		Economic Botanist Bangalore
Armourianum	*G. armourianum*, Kearney		do.
Harkenessi	*G. harknessi*, Brandg		do.
Taitense	*G. taitense*, Pearl		Trinidad West Indies
Tomentosum	*G. tomentosum*, Nutt		Hawaii
(e) *Lintless and Naked :*			
Punjab glabrous lintless	*G. arboreum var. neglectum forma bengalensis, H. and G.*	(Mutant)	Lyllpur Punjab
Dharwar glabrous lintless	do. *forma burmanica H. and G.*		Dharwar
Molisonii glabrous lintless	do. *forma bengalensis H. and G.*		Lyallapur
Hirsutum lintless	*G. hirsutum*		do.

The above mentioned varieties were grown at the cotton breeding station, Coimbatore during 1937 to 1940, which formed the period of investigation. Although recently, Hutchinson, Stephens and Silow [1947] have reclassified the cotton in their Evolution of Gossypium the classification in the above table is maintained

after Hutchinson and Ghose [1937] which existed at the time of investigation on which some of the conclusions were based.

Method

Flower buds were labelled in the field for the purpose of this study prior to flower opening. Ovaries and bolls of different ages were collected periodically as detailed below.

(1) From two days, and 1 day before flower opening ; b. From sixteen hours before and up to the time of flower opening at intervals of two hours. (2) From the time of flowering up to three days after flower opening at intervals of eight hours. (3) From three days to fifteen days old seed, at intervals of one day and (4) From fifteen days old to mature seeds at intervals of two days. The following fixatives* were used.

(a) Allen's modification of Bouin's fluid ; (b) Lavitsky's 5 :5 ; (c) Navashin ; (d) Lacour 2 BD ; (e) Carnoy's fluid and (f) Formacetic alcohol. Seeds from twelve days up to maturity were also fixed and preserved in form-acetic-alcohol for examination of free hand section. The process of washing, dehydration and preparation of paraffin blocks was gone through in the usual manner. Longitudinal sections were cut from 7 to 10 microns in thickness. After the fifteenth day, the seed coats were too hard to be cut with a microtome. Soaking the material for over a week in 25 per cent hydroflouric acid mixed with 50 per cent alcohol did not soften it to the desired extent. Cellulose-acetate in acetone was next tried, but with no improvement. The paraffin blocks when soaked in water for four or five days with seeds partially exposed, softened the outer seed-coat sufficiently, but the contents were often found swollen, distorted and sometimes even disintegrated. It was found swollen, distorted and sometimes even disintegrated. It was found that free hand sections could be used with advantage when mounted in lactic acid as per the method described by Seshadri and Seshadri Aiyangar [1932]. Staining was done in Heidenhain's haematoxylin, gentian violet and Feulgen's nuclear stain [Tomasi, 1936] for material intended for nuclear study, while safranin, gentian violet and light green were used for sections of older ovules. Free hand sections of fresh or preserved material were stained with cotton blue added to lactophenol and mounted in lactoglycerine. Microphotographs of the sections were taken in required cases. Magnifications are given under the respective figures.

Observations

(a) *Epidermal hairs*

Detailed studies were made for this purpose on sections of ovules and seeds of a strain Cambodia's cotton Co. 2 (*G. hirsutum*, Linn.) which bears abundant lint and fuzz on the seed coat. Examination of longitudinal sections of ovules collected from buds one day and two days prior to flower opening showed that epidermal cells were all uniformly rectangular in shape, with their nuclei masked by inclusions of the cytoplasm (Plate XII figs. 1-3). Differentiations in the epidermal cells became

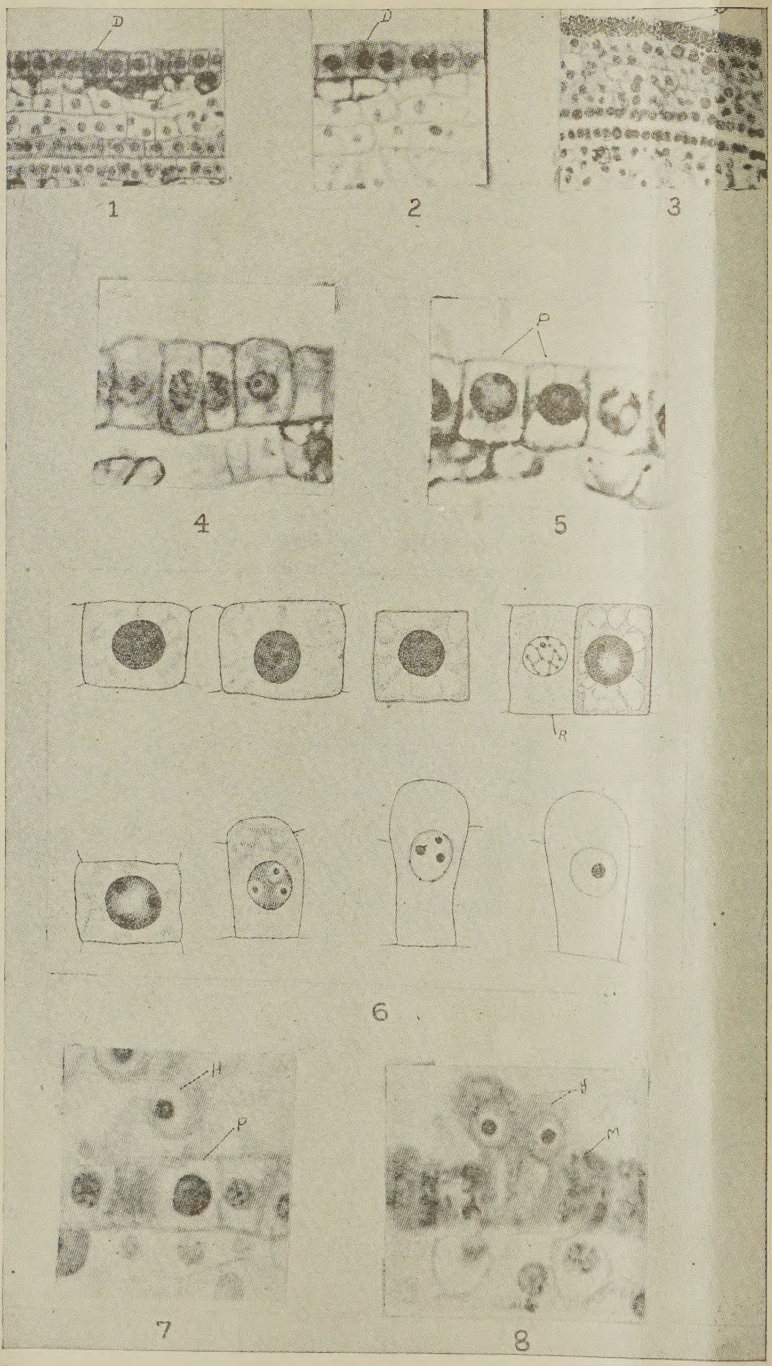
*(a) to (f) for formulae of the killing and fixing fluids, *see* Chamberlion 1932

PLATE XII

1. Photomicrograph : (X 720) : Median longitudinal section of ovule (*G. hirsutum.*) Sixteen hours before flower opening. Differentiating cells with enlarged dark nuclei-'D' in the epidermal layer (chalazal end.).
2. do. 12 hours before flower opening. (region near the equator).
3. Photo-micrograph of ovule (*G. hirsutum*) 2 days before flower opening (X 480).

   Note.—Epidermal cells masked by granular contents—'e'.
4. Photo-micrograph (X 720) :

   Median longitudinal section of ovule (*G. hirsutum*) eight hours before flower opening. Dark nuclei in specialised cells, in stages of clearing and showing nucleoli in them. 'P'. =primordial hair cell.
5. do. Undifferentiated mitotic cells with small nuclei in resting.
6. do. Camera lucida drawings of differentiating cells in various stages of nuclear change in unprotruded and protruded hair initials (X 100). The nature of the resting nucleus 'R' may be noted.
7. Photo-micrograph (X 720) : Ovule (*G. hirsutum*) on the third day after flower opening : P= Primordial hair cell with enlarged dark nucleus. 'H'=Hair with transparent nucleus with a big nucleus.
8. do. newly formed hair at the chalazal region (X 720) M=mitotic division.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first perceptible at the chalazal end of the ovules taken *sixteen hours* before flower opening. At that stage, a few epidermal cells were observed to be bigger than the others and their cell-contents could be distinguished more clearly. The cytoplasm in these was dense and the nuclei were slightly enlarged and homogeneously dark without revealing any details of the nuclear contents (Plate XII, figs. 1-7).

With a view to determine the extent of enlargement, the length and breadth of the primordial hair cells and of the normal cells were determined. Measurements of both length and width of cell and nucleus gave the following averages for 40 cases in each (Table II).

	Dimensions in microns (length × breadth)	
	Cell	Nucleus
Resting	287·3	50·5
Prophase	304·8	71·2
Primordial hair cell	406·2	107·1

It is seen that the primordial hair cells possess bigger cell and nuclear dimensions than those in resting and prophase stages.

The differentiation of the epidermal cells of the ovules can be summarised in the following table.

TABLE II

Differentiation of epidermal cells

Time of observation	Place of differentiation on the ovule	Nature of differentiation
24 hours before flower opening	No differentiation	——
26 hours before flower opening	At the chalazal region	Enlargement of the cell, Vacuolisation of the protoplasm, enlargement of the nucleus in it which was homogeneously dark. (Plate XII, fig. 1)
10 to 12 hours before flower opening	From the chalazal region to the equator.	Formation of larger no. of primordial hair cells. (Plate XII, fig. 2)
8 hours before flower opening	do.	do. and the nucleus in the primordial cells cleared gradually developed one to four small nucleoli and finally became transparent with a single big nucleus. (Plate XII, figs. 4-6)

TABLE II—*contd.*

Differentiation of epidermal cells

Time of observation	Place of differentiation on the ovule	Nature of differentiation
4 hours and two hours before flower opening	From the chalazal region to the equator and upper part of the ovule towards the micropyle.	More hair initials and very few primordial cells
At O' hour (time of flower opening)	All regions of the ovule up to the micropyle	Increase in the number of hair initials and further decrease in the number of primordial cells
At 8 hours and 14 hours after flower opening	do.	Elongation of the hair initials. No primordial cells
Between 14 hours to 56 hours after flower opening	No fresh differentiation.	——
On the third day	Fresh differentiation at the chalazal region amidst elongated hair cells extending up to the micropyle	Second set of primordial hair cells (Plate XII, figs. 7 and 8)
4th and 5th day	Differentiation at the micropyle region for the first time	First set of primordial cells at the micropylar region along with the elongation of the earlier formed second set of cells at the chalazal region
6th and 7th day	Continuation of the above	Second set of primordial hairs at the micropyle and third set at chalazal end. The earlier formed ones developing into hairs and elongating
8th day to 11th day	No change	No fresh hairs formed. The hairs are vigorously elongating

No. fresh primordial cells or hair initials are observable

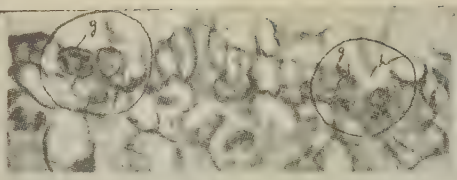
11th day to 24th day. It could be made out from the above observations that three crops of hairs were produced on the ovules from the first to the eleventh day after flowering; that each wave of production started from the chalazal end and extended towards the micropyle, the exception being that the first wave stopped short of the micropylar region, with the result that it appeared, there were only two crops of hairs at that end.

Examination of four other linted naked seeded varieties *viz.* Sea-Island (*G. barbadense*) kidney (*G. barbadense* var. *braziliense*, 1) Ishan (*G. barbadense*, 1) and Moco (*G. hirsutum var. purpurascens*, Poir and two fuzzy seeded Asiatic cottons *viz.* strain 2405 (*G, herbaceum, var. frutescens* H. & G,) and strain of Cocanadas cotton

PLATE XIII

1. Photo-micrograph : (X 480) : Ovule of *G. hirsutum* 11 days old. G=guard cells ; h=hair pushing through the stomata.
2. Photo-micrographs : sections of ovules of Durango 11 days old : (2), (3) and (4) : X 480 , (5) : X 720.

   Showing the successive stages of the mesophyll cell trying to push through the guard cells (a) with empty air cavity ; (b) air cavity filled up ; (c) tier of cells growing in the air cavity and the one below the stomatal pore pressing against the guard cells trying to grow outwards ; (d) Note cells growing out between the guard cells (g) with a mitotic nucleus 'm'.
6. Photo-micrographs (X 720) : Sections of ovules 11 days old : Durango : Note cell beneath the guard cells 'g' trying to push out.
7. X 1000 : Durango : 'g' guard cell with thick walls ; cell pushing out between the guard cells 'h'.
8. (X 720) : Acala : 'g'=guard cell : Note the guard cells are clear and unpigmented. 'h'= stomatal hair.



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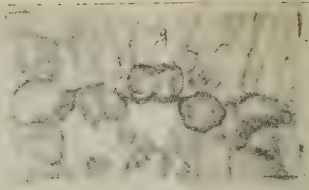

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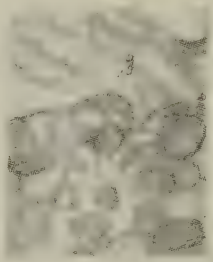

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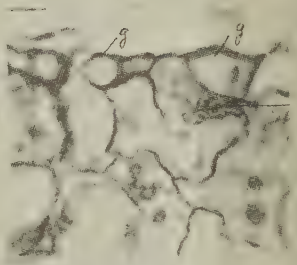

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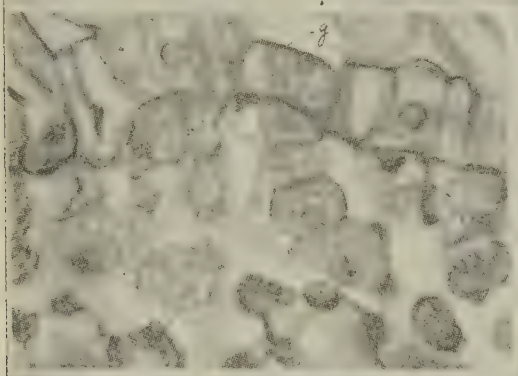

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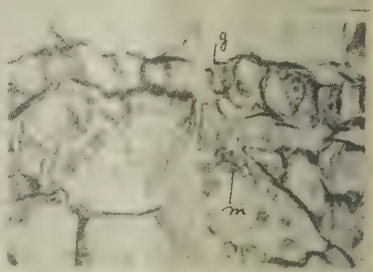

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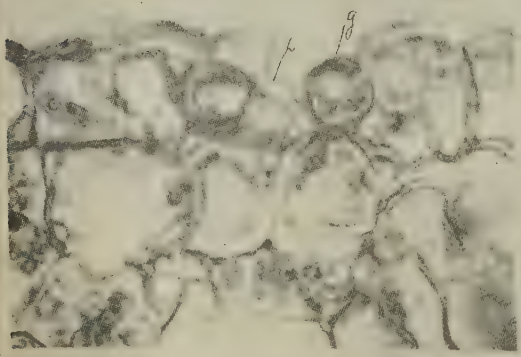

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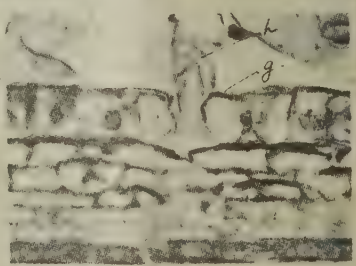

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(*G. arboreum var. nelgectum* forma indica) H. & G. showed that the nature of production of hair initials and their progress in development were exactly similar to the details observed in Co. 2 (*G. hirsutum*) cotton described above. It was, however, noted that in the case of naked seeded varieties, the density of hair production was less and the epidermal cells were longer than in fuzzy seeded cottons. In the case of Asiatic cottons, the number of hair initials at the time of flower opening were fewer and were interspersed with greater number of undifferentiated cells with the result that the bases of the hair cells were not pressed closely at the sides.

(b) *Stomatal hairs*

1. *Linted cultivated cottons.* Examination of the sections of ten to twelve days old ovules, showed remarkable varietal differences in the nature of the stomata and they have been recorded separately [Ayyangar, 1948 b]. In the case of the Sea Island and kidney cottons, the air-cavities were shallower and the guard cells were smaller in size. In Cambodia (Co. 2) the air-cavities were deeper and the guard cells were bigger. In older ovules of the same taken after 12th day, the air-cavities in the section of immature seeds of Cambodia were observed to have been filled up by growing cells and hence reduced in depth. In some cases, the growing cells were seen abutting on the stomatal opening. Such an observation called forth more detailed examination of the sections at closer intervals. The details observed are as follows :

Sections of seeds of Cambodia fixed at different intervals on the tenth day after flower opening, revealed that the epidermal layer contained many cells in mitotic division. The guard cells of the stomata were thick-walled and large with large air-cavities (Plate XIII, fig. 2). On the eleventh day similar stomata were seen with air-cavities being filled up by the multiplication of the mesophyll cells bordering the cavities some of these cells had divided and the daughter nuclei after completion of division could also be seen (Plate XIII, figs. 4, 5). In some cses the daughter cells were found to be pressing against the stomatal pore (Plate XIII, figs. 6 and 3). In certain other cases, the subepidermal cells beneath the stomatal pore were noticed to grow between the guard cells and protrude out of the epidermal layer as hairs (Plate XIII, figs. 1, 7). It was striking to note that these hairs did not manifest in earlier stages, any cytoplasmic and nuclear changes that were associated with the formation of lint hairs. There was no enlargement of the cells, no vacuolisation, and no transformation of the nucleolus. On the other hand, the nuclei were smaller. Photomicrographs of the above features of stomatal hairs are shown in Plate XIII.

On the twelfth day, the sections showed a good number of stomata distributed throughout the surface of the seed coat. Some of them were open, with big air-cavities ; some had their cavities filled up and few others showed fresh protrusion of hairs between the guard cells. The nuclei in the protruded cells lay at the base (Plate XIV, fig 3). Such a feature was in direct contrast with the position of nuclei in the epidermal hairs where they moved out of the epidermis and occupied the middle of the hairs (Plate XII, figs. 8-H). Further the base of new types of hairs was distinctly broader than those of the epidermal hairs.

The differences between the epidermal and subepidermal hairs could be listed thus :

Epidermal hairs	Subepidermal hairs
1. These were formed from the cells of the epidermis from the date of flower opening. In the primordial cells, certain nuclear changes were noticed. The lint nuclei were bigger in size than those of the undifferentiated cells.	These were formed ten days after flower opening from cells beneath the stomata. These cells increased in number by mitotic divisions and filled up the air-cavities beneath the stomata, protruded as hairs between the guard cells without undergoing any further nuclear changes. Sometimes the cells protruded even before the division of their nuclei was completed.
2. The epidermal cells showed enlargement and vacuolisation.	No vacuolisation or enlargement of the cells happened prior to protrusion. Some daughter cells protruded before the cross walls were formed.
3. Soon after protrusion, the nucleus moved into the protruded portion.	The nucleus was small, and remained mostly at the base of the hairs.
4. The base of the hair cells was in line with the bases of the other epidermal cells.	The base of the hair was broader than those of the adjacent epidermal cells, and was below the level of the epidermal layer with guard cells on either side (Plate XIV, figs. 1-10).

After the twelfth day, the above features of the subepidermal hairs were less evident. They could, however, be identified by their broad bases extending below the epidermis, by the guard cell-like appearance of the cells at the flanks, by their constrictions near the base and by their nuclei remaining lower down. In sections of older ovules, the guard cells became indistinct. They were often found fused with their adjacent subsidiary cells possibly due to the pressure of the growing hair between the guard cells (Plate XIV, fig. 8). At later stages, the guard cells lost their characteristic shape and appearance. Hairs from subepidermal layer were observed to protrude out of the stomata up to twenty four days after flower opening. In all cases, such hairs were broadbased, thickwalled and short. In mature seeds, the bases of the two types of hairs were more easily distinguishable. The epidermal hairs were very narrow and pointed at the base, while the subepidermal hairs were broadbased and contained a colouring matter. The cytochrome could be traced continuously from the base to the middle of the hairs (Plate XV, fig. 6). In few cases, seeds from mature

PLATE XIV

Photo-micrographs : showing 'X' stomatal hairs growing between the guard cells (X 720) ovules 12 days old

1. Nandyal 14 : Note clear guard cell in the highly pigmented epidermal layer.
2. Durango.
3. Nandyal-14 (G. *arboreum* var. *neglectum*) : Ovule 15 days old : note subepidermal hair with nucleus at the base. The identity of guard cells on either side is lost. g.=guard cell. (4), (5) and (6) Cambodia (*G. hirsutum*)
7. *G. arboreum* var. *neglectum forma indica* (X 720) ovules 12 days old. 'X' showing broad base of subepidermal hairs.
8. Mollisoni (X 720) Note : the guard cell by the side of the broadbased hair fusing with subsidiary cell.
9. *G. hirsutum* (X 720).
10. Mollisoni (X 600).

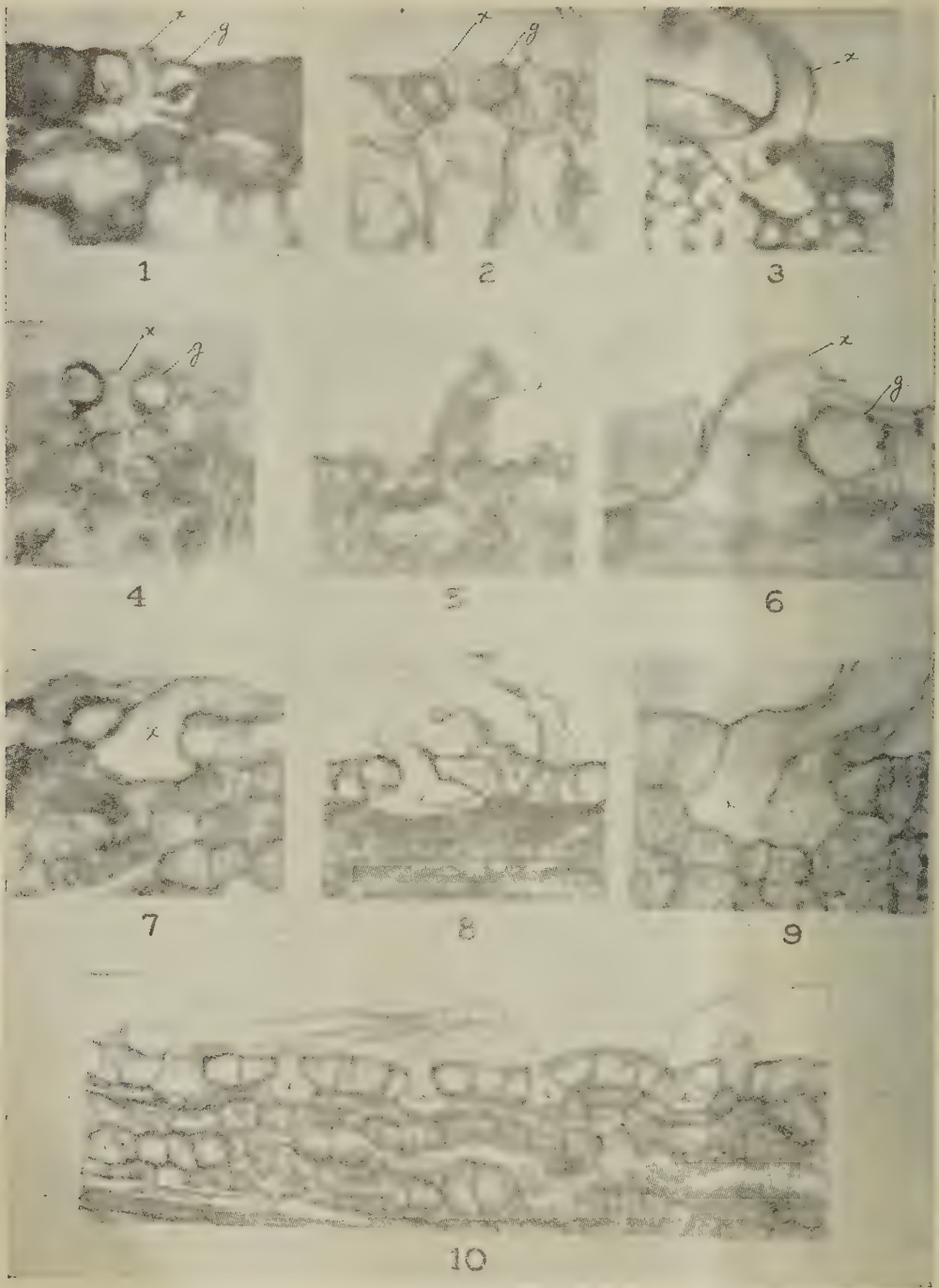
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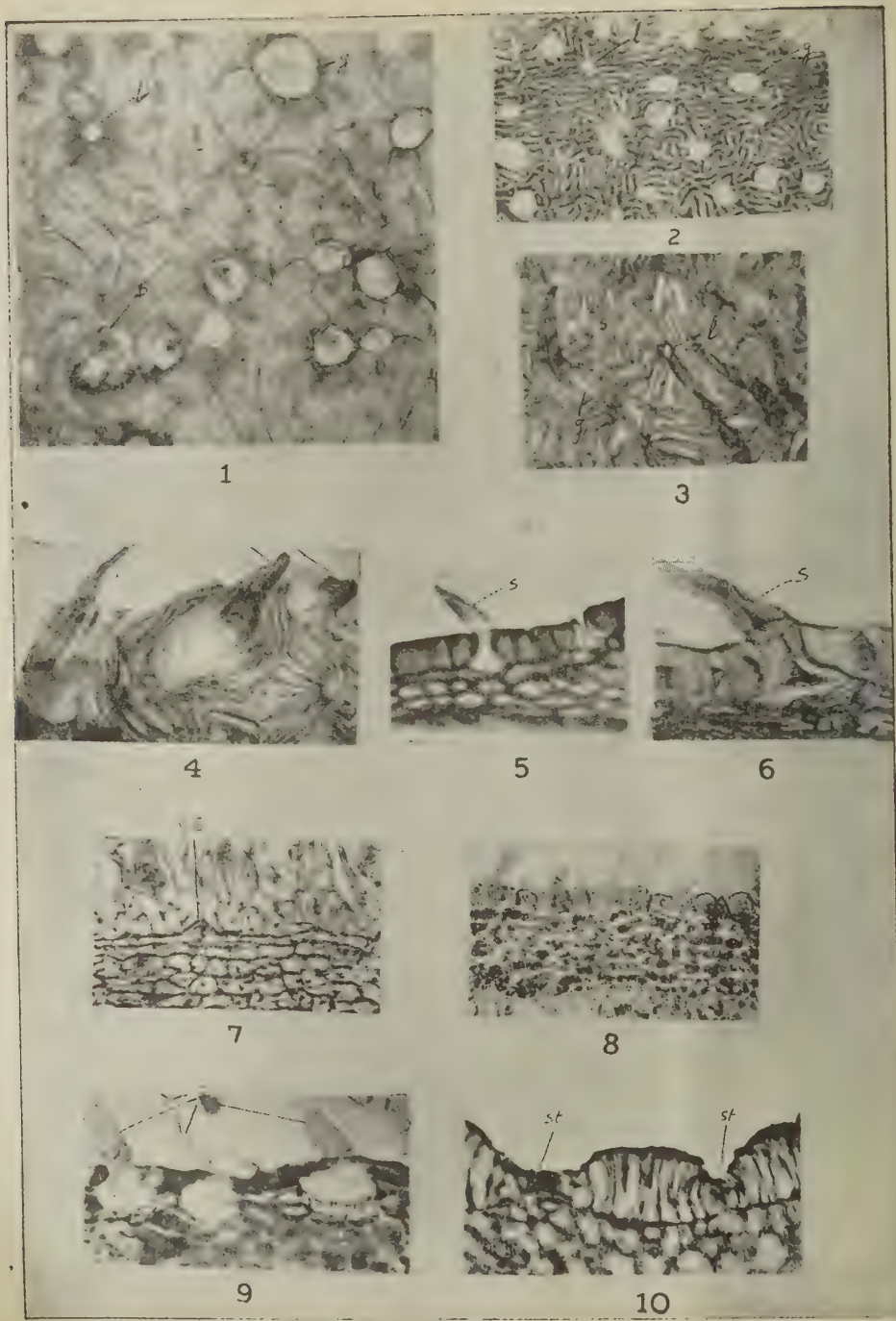
PLATE XV

Photo-micrographs

1. *G. hirsutum* : X 1000. surface view of the mature seed coat.
2. Moco (X 480) (naked type) Note open stomatal pores.
3. *G. hirsutum* (X 480) Note '1' small circles of lint bases, 'g' ring of guard cells and 's' stomatal hair coming out through the opening. The same in (1).
4. *G. hirsutum* : 'S' stomatal hairs.
5. Bourbon. (*G. purpurescens*) : median longitudinal section ; 's' subepidermal hair with broad-base on a fuzzy region of the seed coat.
6. *G. hirsutum* : 's' subepidermal hair ; note cytochrome in the base of the hair.

   (7 to 10) Photo-micropgraphs X 600 :

   Median longitudinal sections of 10 days old ovules.
7. Punjab glabrous lintless : Note thickwalled subepidermal cells pushing outwards (s.e.)
8. Dharwar glabrous lintless : Poor development and elongation of epidermal hairs.
9. Punjab hairy lintless : 'S' subepidermal hairs growing through stomatal pores. Note deep and broad base of the hairs.
10. *Hirsutum* lintless : Stomata blocked by gum. Note the liner epidermal cells with a thick layer of gum over the cuticle.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bolls were soaked in hot water mixed with a little lactic acid for two hours and the peels of the seed coat were taken and their surfaces were examined under the microscope. The bases of the lint hairs were clearly seen as uncoloured small uniform circles (Plate XV, figs. 1 and 3). The stomatal pores were identifiable by hemispherical thickwalled guard cells (Plate XV, fig. 3). They were found filled up by hairs that were also seen protruding out (Plate XV, fig 4). When ammoniacal solution of copper-hydroxide was added gently, the characteristic reaction described by Balls [1920] for fuzz hairs was observable. The hair took a beaded appearance and showed five to ten sharp lamellations in the cell-wall. In contrast to these, the epidermal hairs showed a large number of lamellae. Examination of the five other fuzzy varieties, *viz. Russian hirsutum*, *Lonstar*, *Hartsville*, *Acala* and *Dharwar American* amongst the American group and three varieties *viz.*, *Uppam* (*G. herbaceum*) *Nandyal*-14 and *Mollisoni* from the Asiatic group, showed all the various stages of filling up of the stomatal air cavities found in Cambodia Co. 2. In Acala, however, the broadbased stomatal hairs could not be distinctly made out as subepidermal by the level of their bases, but only by the presence of the guard cells on either side of the hairs which were clear and unpigmented (Plate XIII, fig 8). In Nandyal-14 the stomatal hairs were first noticed as early as the eighth day itself. In *Uppam*, the broadbases of the stomatal hairs were situated more deeply in the subepidermal layer. In *Mollisoni* the bases of the subepidermal hairs were three to four times broader than those of the epidermal hairs (Plate XIV, figs. 8 and 9).

(ii) In the naked seeded types, the development of stomatal hairs found in all the fuzzy types was absent. In sections of seeds of kidney cotton (*G. barbadense linn.* var. *braziliense*) a naked seeded variety, examined from ten days after flowering upto the bursting of the boll the guardcells were found to be smaller and the air-cavities underneath them were shallow. In some, there were indications of disintegration of the mesophyll cells. There was high vacuolisation and shrinking of protoplasm and their outer walls tended to thicken. In sections of ten days old ovules of Ishan (*G. barbadense*, Linn). another naked seeded variety the cells underneath the stomata were found distinctly dead. In Bourbon (*G. hirsutum* var. *purpurascens*, poir) a partially naked seeded variety, the stomatal hairs were few and far between in certain regions, while in the other areas, they were abundant. They showed the same type of origin and development as those seen in sections of Cambodia.

(iii) *Wild Species.* Ovules of four wild cottons with short brown hairs (*G. stocksii ; M. Mast ; G. Davidsonii ;* Kell : G. *armourianum*, Kearney and *G. harkenessi*, Brandg.) were studied in like manner at different stages of growth. In all of them all the changes associated with lint hair formation and their earlier development were noticed. (Plate XVI, figs. 1 to 3.) The primordial cells and hair initials were seen for the first time at the chalazal region of the ovule on the day of flower opening. In later sections, the transformed nuclei were found about the middle of the elongated hairs. In *G. armouriannum*, the lint nuclei were sometimes not spherical. The cytoplasm too was not clear. The rate of elongation was rather slow. The hair bases were broader. Stomata were being formed gradually as in the case of *G. hirsutum* but in smaller numbers. Stomatal hairs were observable in sections

taken after ten days. Well matured stomatal hairs did not however manifest the characteristic fuzz reaction with ammoniacal solution of copper-hydroxide possibly due to differences in the composition of the cellulose deposition. It might be mentioned here that in sections of mature seeds of *G. davidsonii*, the hairs were found matted together and glued to the seed coat, making the seeds appear lintless. When the wax was removed by soaking the seeds in ether, the fibres were seen clearly. (Plate XVI, figs. 2c and d).

It was evident from these, that the wild types, though they appeared to have only fuzz like coatings, produced both lint and stomatal hairs as are found in the cultivated fuzzy cottons.

(iv) *Lintless types.* The ovules of different ages from the following seven lintless types (*vide* Table III) were examined. Dharwar lintless and Mollisoni lintless had ginnable long hairs especially in the chalazal region in small quantities inspite of their being called lintless. American lintless differed from these in being practically naked from the beginning.

TABLE III

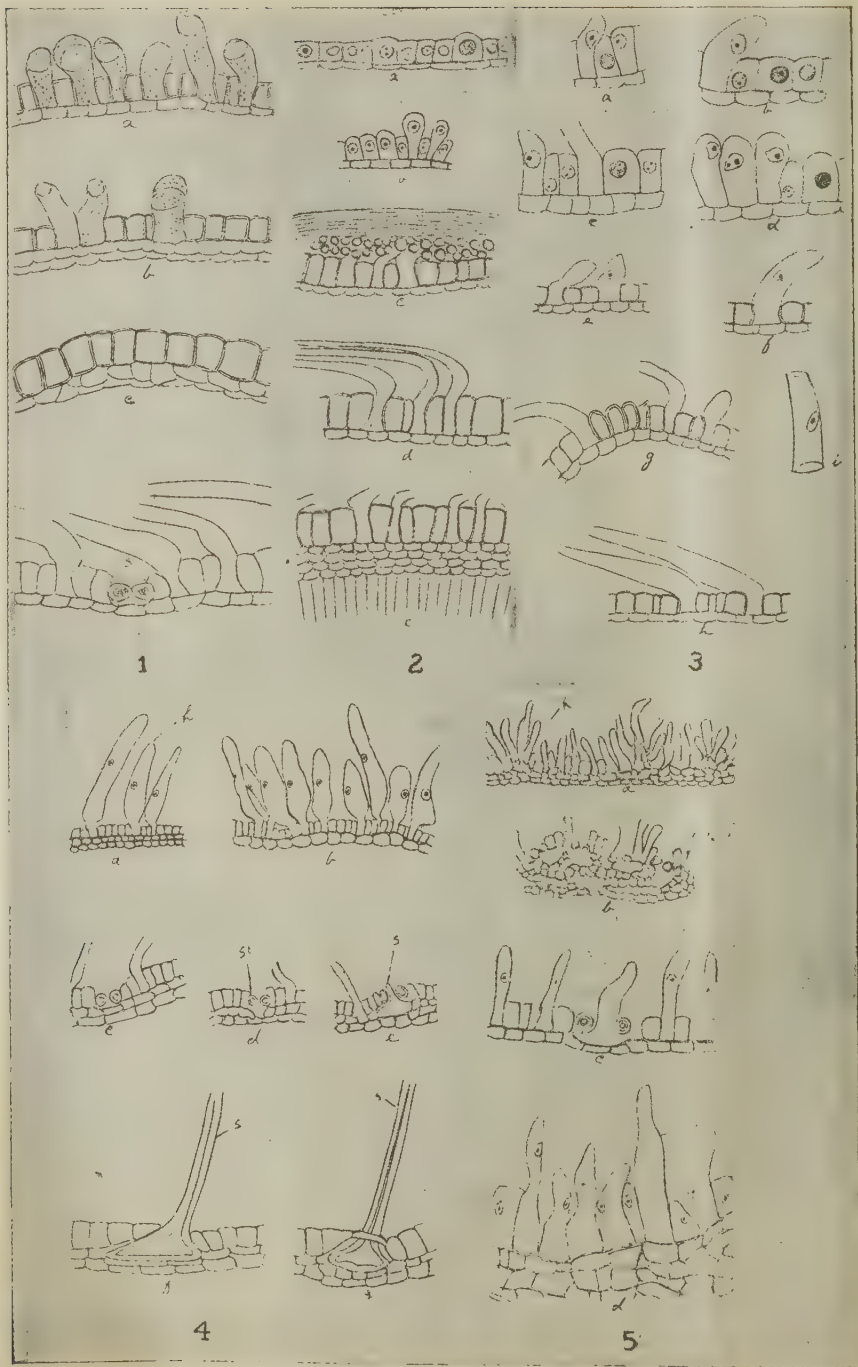
Name of the type	Botanical name	Description of the seeds
1. Punjab hairy lintless	*S. arboreum* var. *neglectum forma bengalensis*	The fuzz hairs are longer and thickly distributed over the entire surface.
2. Punjab downy	do.	The fuzz hairs are very short and make a thick coat over the seed.
3. Nandyal hairy lintless	*G. arboreum* var. *neglectum forma indica*	Similar to (1) but less fuzzy.
4. Punjab glabrous lintless	do. *forma bengalensis*	To the naked eye completly glabrous but under the lens a thick coating of short brown hairs is noticeable.
5. Molisoni glabrous lintless	*G. arboreum* var. *neglectum forma bengalensis*	Naked : Fuzz at the chalazal end. No fuzz at the micropylar end
6. Dharwar glabrous lintless	do *forma buramanica*	More fuzzy than Molisoni glabrous lintless and with some long hairs.
7. American lintless	*G. hirsutum*	Completely naked with two or three long hairs and with no fuzz at all.

The Punjab hairy lintless, Punjab downy, and Nandyal lintless were all similar with regard to the formation of fibres. All of them showed epidermal and stomatal hairs. The former were mostly immature. They differed only in the degree of the lengthening of the epidermal hairs and in the numbers of stomatal hairs produced. Punjab hairy lintless had longer epidermal hairs while Punjab downy had the shortest. But they had more number of stomatal hairs than the Nandyal hairy lintless. (Plate XV, fig. 9 and Plate XVI, fig. 4.)

PLATE XVI

Camera lucida drawings (X 600) ovular sections of G. harkenessi.

1. (a) 5 days old : Note the cut end of the bent epidermal hair.
   (b) 7 days old.
   (c) do. Note the thick-walled epidermal cells.
   (d) 10 days old.
   's' stomata, small and sunken.
2. G. Davidsonni : (X 600) ovular sections :
   (a) One day old : Note primordial hair cell ;
   (b) Two days old : Note hair initials ;
   (c) Seven days old : Note the epidermal hairs all matted together ;
   (d) Ten days old ;
   (e) Mature seed coat : Note all the hairs are epidermal.
3. *G. armorianum.* (X 600) Ovular sections ;
   (a) 1 day old ;
   (b) 2 days old ;
   (c) and (d) 4 days old ;
   (e) and (f) 6 days old ovules : Note want of elongation in the hairs ;
   (g) 10 days old : long hairs are present ;
   (h) 15 days old (i) a bit of long hair with nucleus towards the tapering end. All the hairs are epidermal and epidermal cells become thick-walled after 10 days.
4. A Camera lucida drawings (X 490) : Ovular sections of *Punjab downy* :
   (a) Two days old : Note epidermal hairs 'h',
   (b) Four days old : with more epidermal hairs.
   (c), (d) and (e) ten days old : st-stomata ;
   (f) and (g) nearly mature seed coat.
   's' broad based stomatal hairs.
5. Punjab glabrous lintless (X 480) :
   (a) four days old ovules. Note the growth of the subepidermal cells outwards causing disorganisation of the epidermal layer. Also the large proportion of epidermal cells growing as hairs.
   (b) 10 days old (X 80) 'st'-stomata.
   (c) 11 days old (X 480)- 'st' stomatal hair.
   (d) 12 days (X 480) 'h' epidermal hairs.
   subepidermal layer is made up of thick-walled cells. 'R' ridge.


1
2
3
4
5

Punjab glabrous lintless presented a new feature in having a very large proportion of the epidermal cells transformed into short hairs and in having ridge-like prominences (Plate XV, fig. 7) formed frequently on the seed surface by the pushing out of a few cells of the subepidermal layer. Further, there was a tendency for the walls of this layer beneath the epidermis to thicken and to dislodge the epidermal hairs. The stomatal hairs were very few. The lint hairs elongated very slowly and stopped growing after twelve days.

Molisoni glabrous lintless and Dharwar glabrous lintless were similar in exhibiting small beaked projections from the epidermis in addition to the production of a few long hairs. (Plate XV, fig. 8 and Plate XVI, fig. 5). The beaked projections became cylindrical subsequently' and the lint nuclei were prominent in them as in ordinary lint hairs. (Plate XVI, fig. 1). The micropyle was free from hairy projections. The elongation of the hairs practically ceased after twelve days. No stomatal hairs were met with up to this stage, indicating thereby that they represented the naked seeded type amongst the lintless cottons. The fuzz like appearance was due to the short epidermal hairs present. Dharwar glabrous lintless carried more short hairs than Molisoni lintless.

The Hirsutum lintless type showed an altogether different pattern of lintlessness. On the day of flower opening, no primordial hair cells were met with. Hair initials too were completely absent. On the first day after flower opening, the epidermal cells tended to become narrower and longer due to mitosis. On the second day, an odd stomata or two became visible. In sections taken from bolls ten days old, almost all the epidermal cells showed lengthening (Plate XVII, fig. 2) and (Plate XV, fig. 10) but there was no protrusion of the cells beyond the cuticular layer but for one or two long lint hairs seen occasionally. This suggested that the potentiality of lint production was present in the variety, but it was inhibited by the operation of another factor. The stomata that were present had shallow air-cavities somewhat similar to those observed in naked seeded varieties.

The examination of the lintless types brought out the fact that all these types except the Hirsutum lintless possessed the capacity to differentiate the epidermal cells into hairs and the hair cells underwent all the preparatory cytoplasmic and nuclear changes for the differentiation. (Plate XVII, fig. 3). They only differed in the *rate* of elongation and differentiation of the epidermal cells into hairs. In the Hirsutums lintless, the tendency to form hairs was almost suppressed. With regard to their potentiality for the production of stomatal hairs, Punjab hairy lintless and Punjab downy were the best, and Punjab glabrous lintless was the poorest. Three of them *viz.* Dharwar glabrous lintless, Molisoni glabrous lintless and Hirsutum lintless did not produce any stomatal hairs at all.

Discussion

The observations recorded above point out that (a) some epidermal cells of the cotton ovule undergo certain changes and emerge as hairs and such differentiating cells can be identified in all varieties long before they show themselves up as hairs ; (b) their further elongation is influenced by a number of factors and (c) that in

3A

some varieties, hairs also arise from sub epidermal region, ten days after flowering and (d) these have sequential changes different from those associated with the formation of epidermal hairs.

The bearing of these findings on our present knowledge about the origin and development of lint and fuzz hairs is discussed below.

(a) *Differentiation of hairs*

Balls [1951] as referred to previously declared that all the lint hairs were formed on the day of flowering only. Butt Turner [1929], Gulati [1930], Singh [1931] and Farr [1931] individually concluded that additional hairs could be produced after the day of flowering. Farr [1933] presented further evidences to show that initiation of fibre growth continued over a period of ten or twelve days following fertilisation.

Harland [1929] while discussing the merits of the statements made by Balls [1915] and Turner [1929] on the question, whether hair initiation occurred after the day of flowering preferred to allow the balance of evidence to remain with Balls in the absence of anatomical evidences to the contrary. Though Farr [1933] distinguished young hair cells from normal mitotic cells, in their having more compact and deeply staining nuclei, she did not produce any evidence either by means of illustrations or photo-micrographs to show that young hair cells with differentiated nuclei were present in the section of ovules collected after the day of flowering. The controversial point had, therefore, remained unconcluded. The anatomical evidences obtained in the present investigation would therefore prove important in clarifying the issues.

Barrit [1933] argued that the phenomenon of increase in size of the nucleus reported here, might correspond to that generally observed in prophase stage of mitotis and might not be related to transformation of epidermal cells into hairs. But the actual measurements of the size of the normal cells and their nuclei in resting and prophase, stages as well as in the primordial hair cells (given in Table II) showed clearly that the former cells were 27 per cent smaller than the latter in size. The cells in telophase were only half the size of primordial cells and their nuclei were elliptic in shape in contrast to the spherical shape met with in the primordial hair cells.

The increase in size of the nuclei observed in the primordial hair cells in ovules fixed in alcoholic as well as acetic acid preparations clearly showed that the change was a product of growth process and not the result of fixing and staining reactions. Cases of increase in nuclear size are also on record in many plants as by Haberlandt [1902] in *Lamiinum purpureum*, Tischler [1934] in *Nymphia alba*, Kuester [1916] in *Vanda* and *Catylla*, Heitz [1925] in Moss leaves, Kostoff [1930] and Monschau [1930] in *Tradescantia giaensis*, as a result of differentiation in the function of those cells.

The homogeneous darkening noticed in the nucleus of the primordial hair cells was suspected to have been caused by Heidenhain's haematoxylin used for staining. Attempts at destaining were not successful and other stains like gentian violet, safranin and light green also produced similar homogeneous dense colour on the

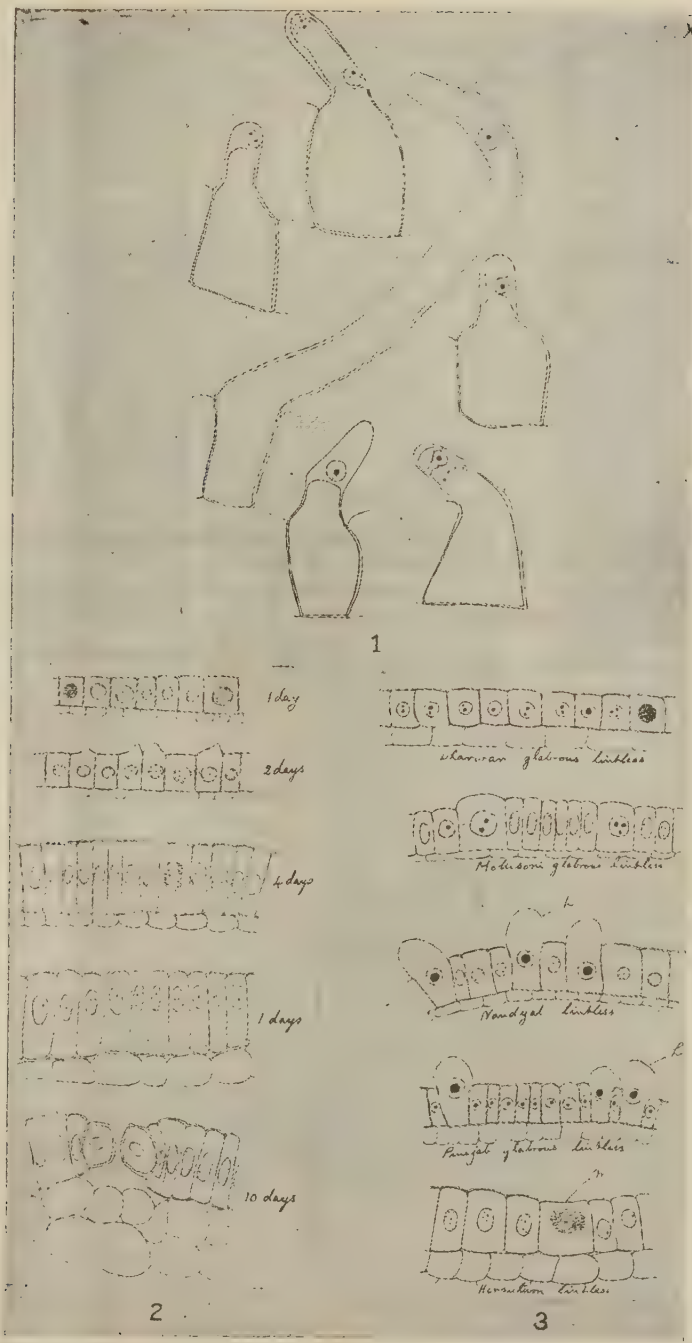

1
1 day
2 days
4 days
10 days
2
Nandyal lintless
Hirsutum lintless
3

PLATE XVII

1. *Dharwar glabrous lintless* : Camera lucida drawings of epidermal hairs on 10 days old ovule with broad based and beaked projections. (X 1000)
2. *Hirsutum lintless* : Camera lucida drawings (X 480) ovular sections showing epidermal layer (10 days). No primordial cells or hair initials are found. Note linear epidermal cells and open stomata.
3. Camera lucida drawings : (X 480) One day old ovules. Primordial hair cells and hair initials are present in all except *Hirsutum* lintless. P.—Primordial cell ; 'h' hair initial ; 'm' milotic nucleus.

nuclei. The fact that such deeply coloured nuclei were found in growing hair initials, precluded the deeper staining from being caused by shrunken uncleus of a dead cell. Though the dark coloration of the nucleus of the primordial hair cell was not obtained when the sections were stained with Feulgen's reagent, the details of nuclear contents were not clear. When counterstained with light green, the green colour spread over the whole nucleus and was held fast. The negative reaction with Feulgen's reagent proved that the dark colour was not due to the presence of chromatin within the nucleus while the deep staining obtained with light green, indicated that the stain was held only on the surface of the nucleus.

Tischler [1934] reported that similar behaviour in the nuclear staining was observed by a number of workers, in cells that were in a state of differentiation. Kuwada and Sagimoto [1928] stated that in *Tradescantia* a mere change in density or form of the nucleus caused differential staining. Showalter [1929] showed that in *Riccardia pingius* and *Ephistis*, the nuclei gave a very strong chromatic staining with iron-allum-haematoxylin and yet remained completely Feulgen negative. He ascribed this reaction to the difference in the chemical constitution of the nucleus at that time. This is very analogous to the condition described in the present studies.

The absence of the enlarged cells with deeply stained enlarged nuclei, (feature claimed here to be precursors of hairs) in *lintless hirsutum* which does not produce any hairs served as negative evidence to show that the sequential changes under reference belonged to the activity connected with hair formation. All the previous workers including Jacob [1943] had not observed the densely stained nucleus of a primordial hair cell even in preflowering stages.

The occurrence of these primordial hair cells in sections taken sixteen hours before flower opening indicates that the stimulus for lint formation has been generated long before flower opening, even when intensive mitotic activity has not started.

Further, the occurrence of these primordial hair cells interspersed with the earlier formed and elongated hair cells in ovules from the day of flower opening up to eight days old, supplies a direct anatomical evidence to say that more than one crop of hairs are being produced on the cotton ovular coat even after the day of flowering. It supports the conclusions arrived at on this point by Gulati, Singh, Farr and Lang clarifying at the same time, the doubts raised by Harland. From the observations recorded in this paper, it would appear that at least three crops of hairs are produced at different regions of seed coat [Koshal and Ahmad, 1932].

The comparative study of several varieties has also been useful in getting an idea of the type of variations present in the initiation of hairs. It was observed that in the lintless types, the formation of primordial hair cells was delayed and slow. In some varieties like Sea Island, the proportion of epidermal cells turning into hair cells was smaller than in Cambodia, while in an uneconomic and practically useless type like Punjab glabrous lintless almost all the epidermal cells tended to become hairs though of a very short length. The pattern of lint distribution also varied widely. In Sea Island and Cambodia, the hair cells were found up to the

end of the micropyle, while in Molisoni glabrous lintless and Dharwar glabrous lintless, no hairs developed for a fairly wide region near the micropyle.

(b) *Elongation of hairs*

This second phase of growth really started on the day of flower opening when the hair initials are first noticed. The mode of further elongation was first described be Weiss and Dippel as early as 1867, later by Balls [1915] and many others. It would not, therefore, call forth much comment except in the case of lintless types which were studied in this aspect for the first time, since they have thrown some additional light on the causes leading to inhibition of hair elongation. Lintlessness exhibited by the *Punjab hairy lintless*, the *Nandyal hairy lintless* and the *Punjab downy* were only different cases of suppression of lint growth, as all the phases of primordial lint formation and of hair initiation were observable in them. *Punjab downy* was shortest due to the very low rates of elongation and its cessation after ten days. Hutchinson and Gadkari [1938] have shown that the *Punjab hairy lintless* is a heterozygote and segregates in the next generation into linted, short linted and lintless types in the ratio of 1 : 2 : 1. The short linted correspond to those of the *Punjab downy* and the lintless to the parent, *Punjab hairy lintless*. It means that the difference in the length between the lintless and the downy is due to the presence of one dose of Lic factor [Hatchinson and Silow, 1939]. In the case of *Punjab glabrous lintless*, the lintlessness would appear to be engendered more by the early disorganisation and separation of the epidermal from the subepidermal layer. In the *Mollisoni lintless*, the peculiar feature is to produce both long and short hairs to a limited degree near the chalazal end. Restriction in the formation of hairs upto a definite region makes those types appear as lintless. Both of these show delayed protrusion. In the early stages, small beak like projections alone are noticed. It is inferred from their appearances that the faculty to elongate is very much suppressed in most of the hairs. When either of them is crossed with the *Punjab glabrous lintless* the F. 1 is linted indicating that the separation of epidermal layer exhibited by the *Punjab glabrous* is prevented by the *Dharwar lintless* while the delayed formation of primordial cells and lack of elongation seen in the latter have been improved by the former. By the union, both are benefited. This explains the mode of inheritance recorded by Hutchinson and Gadkari [1938]. These authors have shown that the two lintless types *Dharwar lintless* and *Punjab glabrous lintless* contained complementary factors for lint production. In the case of *American lintless*, inability to produce primordial lint cells is associated with the absence of hairs on it. All the epidermal cells show elongation similar to that noticed in the naked seeded varieties suggesting thereby that it belongs to that category.

(c) *Stomatal hairs*

The development of hairs through stomata was already described in an earlier part of the paper. On ovules ten to twelve days old in some varieties of cotton. The surface view of mature seed-coats lent further support to the above description. As this feature was not recorded previously, greater

attention was paid to trace the history of its development stage by stage. It was clear from the closer scrutiny of the sections that the mesophyll cells bordering the air-cavity in a few varieties began to divide and fill up the cavity. Eventually one of the cells pushed its way through the stomatal pore and showed itself as a hair. Its mode of differentiation and development were shown to be different from those of epidermal hairs.

Barrit [1933] and Sheffield [1936] doubted the possibility of hairs arising from the parenchymatous cells underneath the stomata.

An examination of section in Plate XIII, fig. 8, would show the guard cells to be free from stain as required by Sheffield. The absence of stomatal air cavity in such sections would be accounted for by the tendency of the cells bordering the cavity to multiply and fill up the space (Plate XIII). This feature would be evident in Plate II, figs. 5, and 7 where new cells would be found endeavouring to reach the stomatal opening. It would be observed by a scrutiny of Plate XIV, figs. 8 and 7, that one of the guard cells was intact while the other was on the point of fusion with the adjacent auxiliary cell of the stoma. The cell-wall between them gradually disappeared and a big cell with the characteristic shape resulted. The course of events in the fusion of the guard cells with the neighbouring subsidiary cells could be followed in Plate XIV. The coalescence of the guard cells with subsidary cells made them bigger than the ordinary epidermal cells. The failure of Sheffield to observe the different stages of development of stomatal hairs could be ascribed possibly to her not examining the sections of ovules of ten to fourteen days old of fuzzy seeded varieties at which period alone they were clearly perceptible.

In the sections of ovules fourteen days after flower opening, two types of hairs could be distinguished, one, in which the bases were in line with those of non-hairy cells of the epidermis and the other, having their bases lower than those of the epidermal cells. In the latter case, it would be observed invariably that the cells on both sides of such hairs were bigger and that a depression on the outer epidermal surface was noticeable (Plate XIV, fig. 10). The sub-epidermal origin accounted for the broad bases. The fusion of the guard cells with the subsidiary cells of the stomata was the cause of the bigger-sized cells at the sides ; the depression at the surface was due to that spot being the position of sunken stoma often met with in such cotton varieties. Barrit [1929] explained that the bases of some of the lint cells became broad due to the pushing down of the hair-bases by the growth of neighbouring cells. If that was the correct explanation, one should expect such type of hairs in all varieties of cotton. In the present investigation, which covered twentynine varieties, broad based hairs were not seen in naked seeded varieties. Such an absence could not be accounted for easily. Further, his argument that the lateral pressure of the cells was the cause for the broad base of the hairs could not explain the bigger size of the adjacent cells and the depression at the epidermal surface associated with the broadbased hairs and their appearance about the fourteenth day as has been admitted by him.

It may be mentioned here that the development of hairs from the subepidermal layer is not an altogether unrecorded phenomenon. De Bary [1877] stated that

the basal cell of a hair body could be placed in the subepidermal layer and hence it would not be uniform with the base of the neighbouring cells. Linsbauer [1930] discussed the relation of the epidermal cells to other cells and gave an instance of an extreme case in scelrides of *Capparis* species, where cells embedded in mesophyl layer pushed themselves out through the epidermis. Rotheret [1900] had mentioned that the crystal cells of Eichornia occasionally forced themselves up to the cuticle. In the case of Citrus, it was noted that the sub-epidermal tissue pushed up by a gliding growth between the epidermal cells. Similar cases were also observed by him in *Dalechampia* and *Roexlianiia*. Poulsen [1919] described analogous behaviour of the lactiferous cells of some of the *Apocyanaceae*. In *Acicanthera spectabulis*, they forced themselves between the cells of the palisades and further up between the epidermal cells and usually they found their way along the sides where three or four cells met. Gaucher [1902] in *Croton cascarilla* recorded that the cells containing tanin would force themselves up to the cuticle.

The observations in cotton ovules were different from the above as multiplication and development of cells happened only in the air chambers beneath the stomata and one of them continued to find its way through the stomatal opening. All these activities took place in enclosed spaces inside the boll far away from the sphere of photosynthetic activity. The conditions were not therefore analogous to the lactiferous or tanin or crystal cells of leaves mentioned by the authors quoted above. That the subepidermal growth was always confined to the cells round the air cavities beneath the stomata was highly suggestive of an attempt on the part of the tissue to *occlude* the stomata on the seed coat. The figure given on page 466 of Haberlandt's "*Phybiological Anatomy of Plants*" looks very much similar to fig. 5 in Plate XIII of this paper which show the growth of cells in the air-cavity beneath the stomata of the ovule. The figure referred to there is a section of leaf of *Pilea elegans* in which the air-chambers on the adaxial side of the leaf become invaded by parenchymatous cells containing abundant protoplasm but few chloroplasts. He has also mentioned that some plants contrive to block up the internal air-chambers of their stomata either during the period of prolonged drought or when the guard cells die or from some other cause lose the power of closing their pores effectively. Most frequently their occlusion depends upon the fact that the immediately adjoining mesophyl cells grow out in the air chamber after the manner of tyloses. The above description very nearly fits in with the conditions of the early stages of development of the sub-epidermal hair described in this paper.

In some varieties the guard cells are big, air-cavities are large and deep at first but they are filled up by the mesophyll cells later in the manner described above. In contrast to the above, in varieties where the stomatal hairs are not in evidence, the air cavities below the stomata are shallow and the cells bordering them disintegrate and lose their activity. It is highly suggestive that the initiation of new crops of hairs on the epidermis demands a greater surface for inter-cellular respiration which is met with by the formation of stomatal air chambers and when stomatal activity is not further required, they are occluded by the creation of dead layer of cells underneath or by the production of new cells and development of hairs through the stomatal pores [Ayyangar, 1948 b.].

(d) *Fuzz hairs*

Having established that some of the cells in the subepidermal regions near the stomata are capable of being transformed into hairs, it is now to be determined whether such hairs will go to form lint or fuzz. Direct evidence for this is not obtainable since in no variety, it is found that all the fuzz hairs produced are exclusively stomatal in origin and further that it is not possible to follow the history of such hairs directly from their initiation to their termination. The fact that the hairs with deeper bases which are identifiable as stomatal hairs have not been so far met with in completely naked seeded varieties leads one to conclude that the stomatal hairs are connected only with fuzz hairs. The observation that in a variety like Bourbon which has both fuzzy and naked regions on the same seed, the stomatal hairs are observed only in the region which is distinctly fuzzy, further strengthens the above inference. But there are also evidences to show that the fuzz is not completely made up of stomatal hairs only. In short linted types with fuzzy seeds like the Punjab hairy lintless, Nandyal hairy lintless, the Punjab downy and *G. stocksii*, the coats of younger seeds are found to contain both the stomatal and epidermal hairs. When tufted or fuzzy tipped varieties like sea island, sakel and Moco are examined under the microscope, the hairs that go to make up the tufts are found to be epidermal in origin if they are near the micropylar and or mostly stomatal in origin if the tufts are at the chalazal end. It is clear from these, that the hairs, that popularly go under the name of fuzz is a composite of both epidermal and stomatal hairs. It may be pointed out that Ayyar and Ayyangar [1933] stated that the fuzz hairs were made up of stomatal hairs only. The present observation being more comprehensive in the number of varieties studied necessitates a modification of that statement.

The relative proportion of these two types of hairs varies with varieties. Amongst the lintless types, the *Punjab hairy* lintless has more stomatal hairs than epidermal while in the *Punjab glabrous lintless* the stomatal hairs form only a small fraction. In contrast to these, the fuzz-like hairs on Dharwar lintless and *Mollisoni lintless* are entirely of epidermal origin. A distinction has to be made here. The seeds of the last two types appear smooth and naked when the hairs are scraped off gently. Hence they really belong to naked seeded variety with short lint hairs similar to *Lintless hirsutum.*

The above conclusion of the origin, time of development and the composition of fuzz hairs is not in complete harmony with that of the previous workers on the subject. It will be further noticed that the fuzz hairs are of later origin than the lint hairs and that part of the fuzz is of sub-epidermal origin while the lint hairs are wholly of epidermal origin.

Summary

Twentynine varieties of cotton consisting of linted and lintless, fuzzy and naked types in wild and cultivated cottons were studied with regard to the determination of origin and development of lint and fuzz hairs. Ovules of different ages from two

days prior to flower opening up to the day of boll opening were collected, fixed and sectioned for the purpose. Their examination showed the following.

Some of the epidermal cells at 16 hours before flower opening began to differentiate by the enlargement of the cell and the necleus, and by the necleus becoming more dense and compact as shown by the deeper staining. These were different from other epidermal cells in mitotic activity. They were found to be primordial lint cells.

These cells first appeared at the chalazala region and extended towards the micropyle.

They were absent from 14 hours to 56 hours after flower opening. This was taken to indicate the cessation of hair formation during that period.

The presence of primordial lint cells and hair initials after 56 hours, amongst grown up hairs was shown to be an evidence from the production of fresh crops of hairs. On that basis, it was inferred from observations, that three crops of hairs are being produced within ten days after flower opening.

Primordial hair cells were not in evidence after ten days.

Cotton varieties were found to differ in the size and depth of air chambers of stomata occurring on the ovular coats.

In varieties with deep air cavities, the mesophyll cells bordering the air chambers, divided, multiplied and filled up the chambers. One of the cells protruded through the stomatal pore and showed itself as a hair. Such a phenomenon occurred only in ovules more than ten days old.

The modes of origin and development of the stomatal hairs were entirely different from those of epidermal hairs.

Stomatal hairs were observed to develop only in fuzzy seeded varieties up to 20 days.

In the naked seeded varieties, the mesophyll cells bordering the cavity were found to disintegrate with no tendency to produce hairs. These changes occurred in ovules more than eight days old.

Four wild and seven lintless types were studied similarly and inhibition of hair growth was found to be associated with the absence of primordial cells. The four wild types were observed to produce both lint and stomatal hairs as in cultivated fuzzy seeded cottons. Amongst the lintless varieties 'hirsutum lintless' had practically no primordial hair cells and stomatal hairs. It had the other features of naked seeded cotton. '*Dharwar lintless*' and 'Molisonii lintless' were found to belong to naked seeded class. The other four, produced both epidermal and stomatal hairs. The lintless condition was found associated with (a) absence of primordial hair-cells; (b) disorganisation and separation of the epidermal layer; (c) delayed orrmation and development of hair cells and (d) low rate of elongation coupled with ea ly cessation of growth.

What is popularly known as 'fuzz' is a composite of both short epidermal fand stomatal hairs.

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ANALYSIS OF SUGARCANE YIELDS

III. INTERRELATIONSHIP OF VARIETIES, NITROGEN, PHOSPHATE AND POTASH

By P. C. Raheja, Agronomist, Indian Agricultural Research Institute, New Delhi

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THE requirements of mineral nutrients are largely influenced by the environmental conditions in which the crop is normally cultivated. Owing to inadequate available supplies of organic manures, artificials are being pressed into service for fertilizing sugarcane crop. Each of the several fertilizers applied have a specific influence on growth and development of the crop and thus on the ultimate yield of cane and sugar. Quantitatively the yield of a crop with increasing doses of a particular fertilizer is not a linear effect. The law of diminishing increments of yields operates. Also, the presence and absence of various nutrients further limits the yield so that expected yield is reduced to the extent a particular nutrient acts as a limiting factor. Therefore, in determining the response of any fertilizer it is essential that other nutrients should be adequately available for the manifestation of the proper response in yield of the crop. As such the determination of quantitative balance amongst the major nutrients, nitrogen, phosphate and potash in any environment for fertilizing sugarcane is an imperative necessity if fertilizers are to economically replace organic manures. With this objective in view experiments were conducted at Agricultural Research Station, Tarnab in Peshawar Valley over a period of six years. The results of these investigations form the subject matter of this paper.

In 1937 Indian Council of Agricultural Research initiated nitrogen, phosphate and potash experiments at all the Sugarcane Research Stations then financed by it. The available evidence from these experiments has indicated that potassic fertilizers either alone or in individual combination with nitrogen or phosphate have not manifested response. By far the largest effect is shown by nitrogen. Phosphate by itself exhibited small effect. But in combination with nitrogen it augmented the beneficial effect of nitrogen. At Shahjahanpur response to nitrogen alone was indicated. Trend of yields for the past 13 years have shown no sign of potash and phosphate depletion. First 100 lb. nitrogen per acre, as ammonium sulphate, gave on the average 288 md. of cane per acre. The next dose of 100 lb. nitrogen resulted only in 40 md. of extra cane yield. Applicaton of nitrogen depressed juice quality while phosphate and potash had little effect. Similar experiments conducted at Gorakhpur, Saraya, Fyzabad, Bijnor, Moradabad and Bulandshahr exhibited an increase in cane tonnage to the extent 10 to 30 per cent over control; phosphate alone had no effect, while a combination of nitrogen and phosphate exhibited effect in North Eastern United Provinces which is contiguous to North Bihar. Cane yields were depressed by potash application at Shahjahanpur, Moradabad and Bulandshahr.

Experiments on sugarcane conducted at Lyallpur and Gurdaspur in the Punjab showed beneficial response to nitrogen application. Application of phosphate and potash did not result in higher tonnage. On the contrary phosphate was observed to depress yields both at Lyallpur and Gurdaspur.

In Bihar, particularly in North Bihar, which forms the main sugar belt, both nitrogenous and phosphatic manures manifested beneficial influence. A dose of 40 lb. nitrogen and 50 lb. P_2O_5 per acre is recommended as top dressing over and above the green manuring with sunnhemp which makes available about 40 to 60 lb. nitrogen per acre. There is evidence that phosphate may beneficially be applied to the green manure crop. At Cuttack phosphate and potash deficiency had not been noticed. About 125 lb. nitrogenous top dressing suffices for optimum returns from the soil.

In South India at Anakapalle, Palur and Gudiyattam, nitrogen alone manifested significant response. A dose of 200 lb. nitrogen was found to be an optimum dose at Gudiyattam. In Mysore at Babar Farm and Irwin Canal Farm experiments did not show response to superphosphate while it was possible to apply economically a dose of 280 lb. nitrogen per acre. In Bombay-Deccan response with nitrogen upto 400 lb. has been observed. There was restricted response to phosphate. Phosphate in combination with potash accelerated both growth and maturity, especially with heavy dressings of nitrogenous manures. Potash application improved keeping quality of cane and reduced pith formation. Beneficial effect of potash as potassium sulphate was noticed in Assam. Besides increasing the yield, such manuring appeared to improve juice quality. Phosphate influenced the cane yield to a lesser extent, Mukherjee and Verma [1949] and Rege [1941]. Borden [1939] observed a rather consistent and uniform ratio of *N. P. K. in sugarcane plant (30N : 10P : 60K). Based on this assumption he tried complete fertilizer mixtures of *N. P. K. on three soil types. Results secured, in terms of sugar yields were not significantly different when some rather wide differences in *N. P. K. ratios were used. Ratios resulting in maximum yields did not conform to the known requirements of the three soils, thereby indicating that an optimum *N. P. K. ratio for complete fertilizer mixture could not be specified.

The previous investigations conducted at Peshawar have indicated that highest net yields were obtained with 150 lb. dose of organic nitrogen or 100 lb. dose of ammoniacal nitrogen Raheja and Azeez [1948] and Raheja [1951]. In normal years higher doses of nitrogen indicated depression in purity of juice. But when the season was unfavourable for normal ripening higher doses had beneficial effect on sugar accumulation in the stalk.

Borden [1939] noticed that juice quality exhibited a positive relationship with the respective N. P. K. nutrient ratios supplied to three widely differing soils. High nitrogen content in the fertilizer mixture resulted in high glucose in juice. Mathur and Haider [1940] and Rege and Sannabhadti [1944] have recorded a similar effect of increasing doses of nitrogen on juice quality.

*Nitrogen, Phosphate and Potash.

Plan and procedure of investigation

A. *Plan.* It was the intention to investigate the relative requirements of N. P. K. nutrients for the growth of two varieties, namely Co. 290 and Co. 312. The former is the standard cane of the Peshawer Valley which is comprised of Peshawar and Mardan districts of the N. W. F. P. and the latter is a variety which had indicated its superior yielding potential in trials conducted upto 1940. Co. 312 was then being tried in cultivators' fields for study of relative performance in general cultivation (Table I).

TABLE I

Treatments under investigation

Varieties	Lb. per acre		
	Nitrogen doses	Phosphate doses	Potash doses
Co. 290 (St)	N_0—*nil*	P_0—*nil*	K_0—*nil*
Co. 312	N_1—50	P_1—37·½	K_1—37·½
	N_2—100	P_2—75	K_2—75

The experiment was continued with the above treatments for four years. Later on finding little differential response in varieties to various nutrient ratios the experiment was run for next two years with Co. 290 alone. So that the design adopted in the first instance was $2\times(3)^3$ factorial experiment in which higher order interactions were confounded with blocks. Later on the experiment had $(3)^3$ design [Yates, 1937]. In both cases number of replications were two.

B. *Procedure of Field Experimentation and Data.* The rotation adopted in this experiment was a two years' rotation, namely,

Maize—Fallow—Sugarcane.

In this very intensive rotation maize was manured uniformly with five tons of compost. Maize was usually harvested in November and thereafter six cultivations were given as preparatory tillage. In first week of March cane planting was carried out in furrows spaced three feet apart in optimum soil moisture. The fertilizer mixtures in different 26 ratios were placed at the bottom of furrows at plough sole. The setts were thus planted at a depth of $4\frac{1}{2}$ inches. The irrigation interval fixed was 10 days but on several occasions periods of drought occurred. That particularly happend in the year 1944-45, during the grand growth period of the crop, due to sudden closure of the canal. As a regular schedule of intercultivation the crop received four intercultivations and one hand hoeing. The soil being light sandy loam, intercultivations helped to conserve soil moisture. The crop was earthed up in third week of July every year.

From the ultimate plot of 1/44th of an acre five clump cane samples were drawn to obtain crusher juice and determine fibre per cent in cane from each of the plots. From the data per cent commercial cane sugar values were calculated to work out recoverable acre sugar yields for each of the several treatments.

Experimental results

1. *Seasonal effect.* The effect of environmental factors is well indicated by the results given in Table II.

TABLE II

Cane yield/acre, C. C. S. per cent values and C. C. S. yield md./acre in different years

Season of growth	Particulars of data		
	Cane yield acre	C. C. S. per cent	C. C. S. yield acre
1941-42	640	6·60	40·3
1942-43	444	8·50	37·3
1943-44	382	9·15	35·1
1944-45	95	7·47	7·3
1945-46	383	8·94	30·7
1946-47	409	8·77	36·2
Mean	389	8·23	31·2

The very low yields of cane in 1944-45 were entirely due to conditions of drought experienced by the crop in that season. Highest cane yields were obtained in 1941-42. In other years the yields were comparable. In years of highest and lowest yields the C. C. S. per cent values were low. In other years the values were comparable. The sugar yield per acre in spite of the very low C. C. S. per cent value in 1941-42 was the highest. Combined analysis of first four years' data indicated significant differences amongst the values of cane yield, C. C. S. per cent values and C. C. S. yield per acre. The differences were as under :

Cane yield md. per acre C. D. @ 5 per cent=33·96 md.	1941-42	1942-43	1943-44	1944-45
C. C. S. per cent values C. D @ 5 per cent=0·719 per cent.	1943-44	1942-43	1944-45	1941-42
C. C. S. Yield md. per acre C. D @ 5 per cent=2·89 md.	1941-42	1942-43	1943-44	1944-45

In the subsequent two years the differences in cane yield and C. C. S. per cent values were not significant, the difference being significant in C. C. S. yield per acre in favour of 1946-47 compared to 1945-46.

2. *Influence of seasons on varieties.* The data for the relationship between seasons and varieties is available only for the first four seasons which is summarised as under :

TABLE III

Effect of seasons on varieties

Year	Cane yield md./acre		C. C. S. per cent value		C. C. S. yield md./acre	
	Co. 290	Co. 312	Co. 290	Co. 312	Co. 290	Co. 312
1941-42	575	706	6·82	6·38	37·7	43·5
1942-43	428	449	8·76	8·28	37·5	37·1
1943-44	407	358	9·46	8·85	38·2	31·9
1944-45	92	99	7·97	6·97	7·5	7·1
Mean	376	02	8·25	7·62	30·2	29·9
C. D. at 5 per cent for interaction SXV			48·02*	Not significant		4·08*
C. D. at 5 per cent for difference between varieties.			24·01*	0·50*		2·04

* Indicates significance at 5 per cent.

In cane yield the differences were significant in two seasons, i.e., 1941-42 and 1943-44. In the other two years the differences were not significant. In the former the difference was in favour of Co. 312 and in the latter in favour of Co. 290. The C. C. S. values did not show significant differences in the various years between the two varieties. Similar differences were observed in C. C. S. yields as in cane yields. The interaction seasons varieties for cane yields and recoverable sugar yields were significant at P=0·5.

The differences in cane yield between the varieties were significant in favour of Co. 312. On the contrary the variety Co. 290 had significantly higher content of recoverable sugar from cane. On the average, therefore, the differences in recoverable sugar yield per acre between the varieties were not significant.

3. *Response to nitrogen doses.* There are six years' data for comparison of the effect of nitrogen doses on cane yields, sugar content and sugar yield per acre. A summary is given below :

TABLE IV

Effect of nitrogen doses on the crop in different seasons

Particulars	Nitrogen doses lb. per acre	Crop seasons: Varieties X N. P. K. Expt. 1941-42	1942-43	1943-44	1944-45	Mean	Crop seasons: N. P. K. Experiment 1945-46	1946-47	Mean
Cane yield md. acre	*nil*	561	435	363	82	360	311	344	327
	50	650	447	397	95	377	374	429	402
	100	697	433	308	108	387	381	455	418
Significance @ 5 per cent	..	Significant	Not significant	Not significant	Significant	Significant	Significant	Significant	(*)
C. C. S. per cent value	*nil*	7·01	8·67	9·46	7·34	8·12	9·08	8·52	8·75
	50	6·66	8·58	8·98	7·37	7·90	8·73	9·00	8·86
	100	6·13	8·26	9·02	7·69	7·75	9·00	8·64	8·82
Significance @ 5 per cent	..	Significant	Not significant	Not significant	Not significant	Not significant	Not significant	Not significant	(*)
C. C. S. yield Mds. P. A.	*nil*	36·6	37·9	34·9	6·1	28·9	27·4	29·6	28·5
	50	42·4	38·3	35·5	7·2	30·9	30·4	39·0	34·7
	100	42·0	35·7	35·0	8·5	30·3	34·4	40·0	37·7
Significance @ 5 per cent	..	Not significant	Not significant	Not significant	Significant	Not significant	Significant	Significant	(*)

(*) *Remarks.*—Detailed data are not available, for combined analysis.

From the results of first four years' *varieties X nitrogen doses, X phosphate doses X potash doses* experiment for two years out of four, the differences in cane yield amongst the three doses were significant. For all the four years the differences were significantly in favour of nitrogen doses. In the two years where results were not significant 100 lb. dose of nitrogen showed a depression in cane yield and this had an adverse effect on the four years' mean results also. It is, therefore, that after omitting the varietal treatment an *N. P. K. experiment was run for another two years. In both these years the response to nitrogen doses in cane yield was significant. In brief, then, in all the six years 50 lb. dose of nitrogen had a beneficial effect. A dose 100 lb. indicated beneficial response in four out of six years. In the four years of favourable response the mean extra yield resulting from the first 50 lb. nitrogen dose was 19·3 per cent and the next 50 lb. dose only 7·0 per cent or an overall increase of 26·4 per cent over no manure treatment.

*Nitrogen, Phosphate and Potash.

A general comparison of C. C. S. per cent values between the different nitrogen doses in the various years indicate that the application of nitrogen depressed the sugar content in cane, except in 1941-42, in all years, the depression being not significant.

In sugar yields, in the first three years, the differences were not significant. They were, however, significant in the next three seasons in favour of nitrogen application to the crop.

4. *Response to phosphate doses.* The doses of phosphate in the experiments extending over six years were 37½ lb. and 75 lb. of P_2O_5 per acre applied as double superphosphate. The responses were as under :

TABLE V

Effect of phosphate doses on the crop in different seasons

Particulars	Phosphate doses lb.	Crop seasons						
		Varieties X N. P. K. experiment				Mean	N. P. K. experiment	
		1941-42	1942-43	1943-44	1944-45		1945-46	1946-47
Cane yield P. A.	*nil*	613	436	397	83	382	346	371
	37½	663	442	378	90	393	385	438
	75	634	437	391	113	394	341	418
Significance @ 5 per cent.	..	Not significant	Not significant	Not significant	Significant	Not significant	Not significant	Significant
C. C. S. per cent value	0	6·73	8·34	9·14	7·12	7·83	8·57	8·58
	37½	6·49	8·75	9·18	7·70	8·03	9·27	8·56
	75	6·58	8·44	9·15	7·60	7·94	8·96	9·02
Significance @ 5 per cent.	..	Not significant	Not significant	Not significant	Not significant	Not significant	Not significant	Not significant
C. C. S. yield P. A.	0	40·6	36·5	34·8	6·0	29·5	27·8	31·8
	37½	40·5	38·7	34·7	7·1	30·3	36·8	38·4
	75	40·6	36·7	36·0	8·7	30·5	27·6	38·5
Significance @ 5 per cent.	..	Not significant	Not significant	Not significant	Significant	Not significant	Significant	Significant

On the whole the effect of the two doses of phosphate was not indicated on the crop yield. Similarly the differences in sugar content were small and not significant. Response in sugar yield per acre were also not consistent. On the whole the beneficial effect produced was small.

5. *Response to potash doses.* The potash was applied as potassium sulphate at level of 37½ lb. and 75 lb. K_2O per acre for comparison of the response against no potash application. The results are summarized in Table VI below :

TABLE VI

Effect of potash doses on the crop in different years

Particulars	Potash doses lb./acre	Crop season						
		Varieties X N. P. K. experiment				Mean	N. P. K. experiment	
		1941-42	1942-43	1943-44	1944-45		1945-46	1946-47
Cane yield md./acre	0	612	440	387	99	385	375	446
	37½	658	456	403	93	403	345	396
	75	654	419	358	93	381	346	385
Significance @ 5 per cent.	..	Not significant	Not significant	Not significant	Not significant	Not significant	Not significant	Significant
C. C. S. per cent value	0	6·46	8·61	9·32	7·65	8·01	8·99	9·02
	37½	6·80	8·58	9·17	7·32	7·97	8·72	8·47
	75	6·45	8·42	8·97	7·44	7·84	9·10	8·68
Significance @ 5 per cent.	..	Not significant	Not significant	Not significant	Not significant	Not significant	Not significant	Not significant
C. C. S. yield md./acre	0	38·1	37·8	36·0	7·6	29·9	31·6	40·6
	37½	44·5	39·0	37·0	7·9	32·1	30·6	34·5
	75	39·2	35·2	32·2	7·3	28·5	29·6	33·6
Significance @ 5 per cent	..	Significant	Not significant	Not significant	Not significant	Significant	Not significant	Significant

The differences in tonnage of the crop were not significant in five years out of six. In the sixth year the fertilizer acted as depressant. Although the results, on the whole, are not significant the double dose of potash had rather a depressing effect compared to single dose. The sugar content in cane was depressed rather than improved by potash fertilization. In gross yield of sugar per acre the single dose of potash had beneficial effect when results of the first four years were taken together. In the subsequent two years no potash treatment gave higher sugar yield per acre. Generally, then, the application of potash had not indicated any beneficial effect.

6. *Interactions amongst varieties, nitrogen, phosphate and potash.* It was possible to analyse the combined data of the first four years and it was noticed that neither of the interactions N. P., N. K. and P. K. were significant for cane yield, C. C. S. per cent values or for sugar yields per acre. But some interactions were observed to be significant in individual years (Table VII). In 1941-42 varieties and phosphate showed significant difference in their responses at 5 per cent level of significance

Without phosphate and 37½ lb. dose of P_2O_5 to Co. 290 the C. C. S. per cent values were significantly superior to those of Co. 312. While 75 lb. phosphate application though superior in Co. 312 was not significantly so to that of Co. 290. In 1944-45 the cane yield response due to N. P. and P. K. interactions were significant. Again interaction of potash and phosphate in 1941-42 showed significant effects in C. C. S. values of crop. In 1942-43 and 1943-44, the interactions between nitrogen and phosphate were significant. Higher doses of nitrogen and phosphate showed better juice quality than lower doses of these nutrients. Interaction P. K. and N. P. in 1943-44 were significant for sugar yield. In no other year such relationships were observed.

TABLE VII

Interaction responses of nutrients in various years

Particulars	Nature of inter-actions	Crop seasons				Remarks.
		1941-42	1942-43	1943-44	1944-45	
Cane yield md./acre	NP	..	..	..	Signi-ficant**	* Indicates significance at 5 per cent level
	NK	..	..	..	..	
	PK	..	..	..	Signi-ficant*	** Indicates significance at 10 per cent level
C. C. S. per cent value	NP	..	Signi-ficant**	Signi-ficant*	..	The complete data for 1945-46 and 1946-47 being not available interactions have not been reported
	NK	..	..	..	..	
	PK	Signi-ficant	..	..	..	
C. C. S. yield md./acre	NP	..	..	Signi-ficant**	..	
	NK	..	..	..	..	
	PK	..	..	Signi-ficant*	..	

Thus from the overall analysis it appears that in certain years N. P. treatments showed significant responses in cane yields ; C. C. S. per cent values or sugar yields per acre. This was indicated to a lesser extent for P. K. treatment also. In other words there seems to be some necessity of fertilizing with phosphate when nitrogen is applied. It is possible that by placement of phosphate the crop may have greater availability from the soil, and then a more consistent response may be indicated. In this direction preliminary observations on phosphate placement indicate superior response and better utilization phosphate and nitrogen for crop growth.

Significance of the results

Stewart [1929] had collected evidence to show that ratio of $N : P_2O_5 : K_2O$ at various stages in the life of the sugarcane plant approximated to 30 : 10 : 60 (=100). The analysis of the crop had been carried out at 1½ months, 3½ months, 5 months, 8 months and 12 months. Similar data had been reported by Wolters [1929] from

another site. There the crop at various stages of its growth had shown N : P_2O_5 : K_2O ratio of 26 : 8 : 66 which is not very much different from 30 : 10 : 60 ratio reported by Stewart. Rege and Sannabhadti [1943] observed a ratio of 3 : 1 : 9. They explained high potash value due to high content of potash in soil. Borden [1939] experimenting on Yamada soil observed that differences in yield or quality were not indicated when the ratio of K to a constant N : P ratio was changed. When the N ratio, associated with a 1 : 1 : : P : K ratio, was increased both cane yield and quality were adversely affected. With a 1 : 1 ratio of N to K there was no reliable difference in cane or quality with change in P ratio ; however, with a 1 : 2 ratio of N to K the quality was better when P was high. On the whole with rather wide differences in the N : P : K ratios he did obtain significantly different sugar yields and the ' best ' yields were generally not in conformity with the known requirements of the various soils on which he conducted experiments.

In the experiment, on the whole, application of nitrogen gave significantly higher cane yield than no top dressing of the ammonium sulphate. In four years, when both doses (50 and 100 lb. N) indicated graded increase, first 50 lb. gave 19·3 per cent extra tonnage and the next 50 lb. 7·0 per cent more cane yield. Increase in nitrogen dose with a constant ratio of P : K adversely affected the quality. Such a decrease in the concentration of sucrose was also observed by Rege and Sannabhadti [1944] and Das [1936]. Thus nitrogen enhanced the sugar yield upto 50 lb. dose. With 100 lb. dose the season made a difference either way in sugar yield. Phosphate neither markedly affected the cane yield, sugar content or sugar yield of the crop. With a constant ratio of K, in some years there was evidence to show that increasing doses of N: P had beneficial influence on cane and sugar yields. Rege and Sannabhadti [1943] observed ' slower deterioration in the keeping quality of cane after the attainment of maximum brix in the case of phosphate treatment than in the other one '.

The application of potash at two levels ($37\frac{1}{2}$ and 75 lb.) compared to no application did not manifest beneficial response in cane yield. The sugar content, on the whole, was somewhat depressed rather than improved by application of potash. Because of higher cane yield with the single dose the sugar yield improved when results of first four years were considered together.

In two years, i.e., 1941-42 and 1943-44 interaction between potash and phosphate was significant for C. C. S. per cent value of the crop.

Gregory and Crowther [1928 and 1931] established 'differential varietal response' in utilization of nutrients in the production of barley. Lynas [1936] observed large differences in susceptibility to phosphate deficiency amongst 21 varieties of corn. Besides, the response to phosphate was correlated with the characters of the root system. Under field conditions differential response in varieties has been established by Lamb and Salter [1936], Woodford and McCalla [1936], Crowther [1933] and Crowther, Tomforde and Mahmoud [1936]. In 1941-42 the interaction between varieties and phosphate had indicated significance. The differential response to phosphate manuring could be had in one year. Such interactions were observed in the several years between varieties and nitrogen or potash. Varieties, however, behaved differently in relation to seasons.

Summary

A multiple-factor experiment $2x(3)^3$ design consisting of two varieties (Co. 312 and Co. 290), three levels of nitrogen (*nil*, 50 lb. and 100 lb. nitrogen per acre), phosphate (*nil*, $37\frac{1}{2}$ lb. and 75 lb. P_2O_5 per acre) and potash (*nil*, $37\frac{1}{2}$ lb. and 75 lb. K_2O per acre) was conducted for four seasons. Later on an N. P. K. experiment of $(3)^3$ design was run for two seasons. The data obtained over those six years have indicated the under-mentioned results—

The environment influenced the cane yield, quality of crop and sugar yield in the various years. Varieties responded differentially to the environment.

On the whole nitrogen manifested a beneficial response in growth of the crop rather than accumulation of sugar so that crop yield improved with increasing doses of nitrogen but C. C. S. per cent value was lowered. Generally sugar yield was higher with 50 lb. dose of nitrogen. The environment influenced markedly the sugar yield with 100 lb. dose of nitrogen. Application of phosphate at two levels, neither affected crop growth nor the sucrose content of the crop. But combined with nitrogen it had beneficial effect in some years than in others.

Dressing with potash did not improve the cane yield. Sugar content was somewhat depressed rather than improved by application of potash. With single dose ($37\frac{1}{2}$ lb. K_2O per acre) of potash, because of increase in cane yield, the sugar yield obtained was higher than control treatment, the difference being not significant.

The experiment does not suggest a fixed ratio of N : P : K for a fertilizer mixture for high sugar yield. But there is evidence that with higher nitrogen dressing application of phosphate is likely to prove beneficial. In one year the interactions between varieties and phosphate dressing indicated significance.

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ANALYSIS OF SUGARCANE YIELDS

IV. VARIETIES X PERIODS OF PLANTING X IRRIGATION INTERVAL EXPERIMENT

By P. C. *Raheja, Sugarcane Specialist, North-West Frontier Province

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THE establishment of the crop depends upon the germination which in turn depends upon the environment. The sprouting of the bud is primarily controlled by factors of soil moisture and temperature. These conditions being favourable the speed of sprouting, higher percentage of bud germination and rapid development of shoot is ensured under field conditions. Subsequent development is controlled by such factors as sunshine, relative humidity, available plant food supply, soil aeration, weed control, protection from pests and diseases, etc., besides temperature and soil moisture. Under field conditions some of these factors can be controlled by a change in the date of planting, and change in the irrigation interval. With a view to study the effect of these two factors an experiment was conducted for five seasons. That the varieties might show differential response to these factors was taken into consideration and two varieties widely differing in their growth characters were included in the series.

McMartin [1946] investigating the effect of chemicals on the propagation of sugarcane observed that cane cuttings did not absorb moisture to initiate shoot and root development. It was the subsequent development of these that depended upon high moisture content. Van Dillewijin [1948] noted that it was under unfavourable conditions that pretreatment of cuttings with water or aqueous solutions of chemicals brought about better and quicker germination. Rege *et al.* [1939] observed that temperatures below 50°F. were positively injurious for sprouting of cane buds. Clements [1940] recorded that soil temperature slightly above 70°F. were nearly marginal for germination. Below this limit the successive decreases caused rapid decrease in per cent germination and increase in the time of emergence. He considered that soil temperature is one of the most important single factor operating in relation to cane germination under field conditions. While reviewing the work on the germination of sugar cane Leake [1948] stated that the germination is slow below 70°F. and increases upto an optimum within temperatures 88-97°F. Harrington [1923] and later on Morinaga [1928] have shown that alternating high and low temperatures hasten germination of seeds and bulbs. Das [1931] considered that similar reaction of sugarcane would not only promote quick bud germination but induce early suckering, resulting in greater number of mature millable stalks at harvest and a higher sucrose content in the harvested crop. Rosenfeld [1918] reported results of two experiments conducted at Tucuman Sugar Experiment Station, Argentina. Plantings were carried out at regular intervals all the year round. March, April and May plantings suffered severely from frosts

* Now Agronomist, Indian Agricultural Research Institute, New Delhi.

in June (in the southern hemisphere). Plantations from 15 July to 15 September gave better results, September planting being the best from yields at harvest point of view.

Rege and Patwardhan [1945] conducted experiments to study performance of various varieties in different plantings. The three common practices of planting in Bombay-Deccan are (1) *adsali* or post seasonal planting starting in June, (2) pre-seasonal planting starting in October and (3) *suru* starting in January. The mean data recorded for three seasons indicated highest yield per acre from July planting and minimum tonnage from January planting. January planting also gave poor juice quality. Although October planting resulted in higher tonnage than January planting, due to larger suckering, the juice quality of the crop was poor so that sugar yield per acre was low. Some of the varieties, as Co. 419, when started in July exhibited early maturity than October or January planting. Varieties indicated differential response to various plantings. Lauritzen, Brandes and Matz [1946] have indicated an interaction between light and temperature. At various temperatures there occurred an increase in growth with an increase in light intensity. For each temperature there was minimum of light intensity for survival, health and growth. Temperatures have profound influence on accumulation of sugars. This has amply been demonstrated by Das [1931]. Clements [1940] stated that if temperatures are unfavourable shallow planting will to a great extent mitigate the ill effect of low temperatures by the slight warmth obtained during the day. Discussing the effect of soil aeration and soil moisture he stressed the importance of planting shallow in cool, poorly aerated and poorly drained soils and deep planting in well drained soils especially when temperatures are high.

Experimental

In the temperate climate of Northern India the two planting seasons are (i) spring and (ii) autumn. It is more common to plant in early spring, *i.e.*, between mid-February to late in March. Autumn planting is preferred where it is desired to cover a large area with limited resources or where it is intended to obtain early maturity of the crop. Frosts are common in Peshawar valley and it is the attempt of the farmer to bring about early maturity. It was, therefore, considered desireable to plant in autumn to obtain early germination and induce early suckering and thereby obtain higher quality ratio in the crop. In a previous publication advantage of applying water at critical stage of soil moisture limit has been indicated. This factor of irrigation interval was combined to the treatments of autumn versus spring planting. In order to study the varietal response to these treatments two varieties included in the trial were Co. 290, the local standard and Co. 312, a variety susceptible to low temperatures.

The rotation adopted for the experiment was as under :

Maize—*shaftal*—sugarcane.

The experiment was run at four different sites in the four years for which data on cane yield and sugar recovery have been separately worked out. Maize crop was sown in early July. In the standing crop of maize, the seed of *shaftal* (*Trifolium*

rasupinatum) was broadcast in September every year. Cane was planted in the month of November after removing the maize stubble. Three budded sets of the two varieties Co. 290 and Co. 312, were planted, end to end, with buds facing to the sides of the furrows. These were lightly covered over with the soil hardly to a depth of 2 in. below the soil surface. *Shaftal* was cut five times in each of the years, the fifth cutting was spread on the ground and ploughed in as green manure. At planting 20 lb. nitrogen per acre was spread in the furrow and mixed with the soil. Soon after planting land was irrigated. Late in May a further top dressing of 20 lb. nitrogen as ammonium sulphate was given to the crop. That was hoed in and land was irrigated thereafter.

Notes on germination were recorded. Record of growth at regular intervals was maintained. The crop samples were drawn at harvest for determining juice quality. Yield of cane was recorded at harvest, carried out in February every year. These data have been analysed as a serial experiment.

Observations and yield data

A. *Germination*

In all the years the November planted crop showed poor stand of the crop till the spring season. The germination hardly exceeded five per cent of the buds planted. The spring planted crop rapidly germinated and gave approximately 50 to 55 per cent stand by the end of April. By then the stand of the autumn crop was estimated at 45 to 50 per cent only. The shoot emergence from the soil actually was delayed in most of these cases by 4 to 4½ months. So that temperatures during the period November to March were sub-optimal for germination. A record of these temperatures is given as under :

Table I

Temperature variations in various months

Particulars	Year	Period of germination					
		November	December	January	February	March	April
Mean maximum temperatures °F.	1941-42	79·8	70·2	61·5	68·0	79·6	89·6
	1942-43	83·1	64·0	64·5	70·5	83·3	86·0
	1943-44	82·3	71·6	62·7	66·7	74·9	82·9
	1944-45	77·6	71·2	61·2	68·4	75·3	84·4
	1945-46	75·0	67·5	66·5	70·8	72·7	91·4
	Mean	79·6	68·9	63·3	68·9	77·1	86·9

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TABLE I—*contd.*

Temperature variations in various months

Particulars	Year	PERIOD OF GERMINATION					
		November	December	January	February	March	April
Mean minimum temperatures °F.	1941-42	44·2	39·6	38·1	41·9	51·4	63·4
	1942-43	47·0	33·0	38·0	40·2	46·6	61·9
	1943-44	42·3	38·9	36·9	40·4	51·4	58·4
	1944-45	43·5	33·5	34·8	35·7	47·3	58·3
	1945-46	46·2	33·0	37·7	46·2	51·2	61·8
	Mean	44·6	35·6	37·1	40·5	49·6	60·7
Mean daily temperatures °F.	1941-42	62·0	54·8	49·8	54·9	65·5	76·6
	1942-43	65·0	48·5	51·2	55·3	64·9	73·9
	1943-44	62·3	55·2	49·8	53·5	63·2	78·4
	1944-45	60·6	52·3	49·5	52·0	61·3	71·6
	1945-46	60·6	50·2	52·1	58·5	61·9	76·6
	Mean	62·1	52·2	50·5	54·8	63·4	75·4

From the temperature observations summarised in the above table, it is evident that in the November month the mean maximum temperatures were above 70°F. and the mean minimum temperatures were below it. The minimum temperatures were very much reduced in the months of December and January. In December and January the mean maximum temperatures were also below 70°F. It was in February and subsequent months that temperatures had a tendency to go up. Average temperatures in the months of March and April ranged between 65 and 75°F. It was, therefore, that in spite of the shallow planting within the depth of 2 in. of the surface soil and ample supplies of irrigation water to the *shaftal* and cane crops the germinaton of the November planted crop was delayed by about 4 to 4½ months. These observations confirm the findings of Clements [1940] that mean temperatures below 70°F. are sub-normal for germination. The germination of Co. 312 was adversely influenced compared to that of Co. 290.

B. *Growth data*

The growth data were recorded during the season 1941-42 which are summarised as under :

TABLE II

Mean monthly growth values 1941-42 periods of planting X varieties X irrigation Intervals series

Treatments	Growth in cm. in various months							
	Upto April	May	June	July	August	Septem-ber	October	Novem-ber
$P_0 v_0 i_0$	8·6	10·4	35·5	46·6	59·2	43·5	35·3	4·2
$P_0 v_0 i_1$	9·5	9·2	21·8	34·8	58·2	31·1	27·3	4·4
$P_0 v_1 i_0$	10·8	14·2	31·8	47·3	59·1	32·9	31·8	7·7
$P_0 v_1 i_1$	9·0	9·4	26·4	34·8	53·9	27·8	23·0	3·8
$P_1 v_0 i_0$	10·8	10·5	37·7	46·4	58·0	44·8	29·7	8·0
$P_1 v_0 i_1$	10·5	11·0	29·7	34·9	54·4	24·8	21·0	8·0
$P_1 v_1 i_0$	11·8	15·5	37·4	50·9	57·8	41·8	31·6	8·9
$P_1 v_1 i_1$	6·2	11·1	34·6	41·5	60·9	28·7	21·6	7·4

The above figures are mean values of ten observations in one of the representative replications of the experiment. For the purpose of comparing the effect of period of planting the mean values for eighty observations are given as under :

TABLE III

Effect of period of planting on mean monthly growth of the crop 1941-42

Treatments	Growth in cm. in various months								
	Upto April	May	June	July	August	Septem-ber	October	Novem-ber	Total
November planting	9·5	10·8	28·9	40·9	57·6	33·9	29·4	5·0	215·9
March planting	9·8	12·0	34·8	43·4	57·8	35·5	26·0	8·1	227·4

It is evident from the record that the growth was arrested by low temperatures from November to March. So that the growth in height of the March planted crop was somewhat better than the autumn planted one. In fact upto July it had higher level of growth. The total growth from August to November was almost equal in both the crops, namely 125·8 and 127·4 cm. respectively. Upto July the set back to growth of autumn crop was 10 cm. i.e. in the stage earlier to the month of August.

TABLE IV

Effect of period of planting on the growth of two varieties

Treatments	Growth in cm. in various months								
	Upto April	May	June	July	August	September	October	November	Total
November planting—									
Variety Co. 290	9·0	9·8	28·6	40·7	58·7	37·3	31·3	4·3	219·7
Variety Co. 312	9·9	11·8	29·1	41·0	56·5	30·3	27·4	5·7	211·7
March planting—									
Variety Co. 290	10·6	10·7	33·7	40·6	56·7	34·8	25·3	8·0	220·4
Variety Co. 312	9·0	13·3	36·0	46·2	59.3	35·5	26·6	8·2	234·1

In Table IV have been summarised the data for the effect of period of planting upon the varieties. Though initially the November planted crop of Co. 312 was slightly better than Co. 290, in the later stages the initial advantage was not kept maintained. So that total growth in height of the plants on the average were 8 cm. less than Co. 290. On the contrary the spring planted crop of Co. 312 throughout showed better growth than that of Co. 290 which resulted in difference of 13·7 cm. Thus variety Co. 290 performed equally well when planted in November or March. But it made a difference of 22·4 cm. between the autumn and spring plantings in variety Co. 312.

Growth data for the remaining years were not recorded systematically.

C. *Cane and sugar yields*

1. *Periods of planting.* The effect of periods of planting was variable in the different years. The harvest results are given as under :

TABLE V

Effect of periods of planting on cane yield, C. C. S. per cent value and recoverable cane sugar per acre

Particulars	Harvest years					
	1941-42	1942-43	1943-44	1944-45	1945-46	Mean
November planting—						
Cane yield md.	677	996	330	296	375	535·3
C. C. S. per cent value	6·64	5·54	10·66	6·46	8·31	7·52
C. C. S. yields md.	43·6	55·1	33·6	18·8	30·4	36·3
March planting—						
Cane yield md.	691	929	343	309	291	512·6
C. C. S. per cent value	6·06	5·90	10·45	7·26	9·10	7·72
C. C. S. yields md.	41·1	54·9	36·7	29·0	31·0	38·6
C. D. at 5 per cent—						
Cane yield md.	Not significant	Not significant	Not significant	Not significant	66·2	Not significant
C. C. S. per cent values	Not significant	Not significant	Not significant	Not significant	0·60	Not significant
C. C. S. yield md.	Not significant	Not significant	Not significant	Not significant	Not significant	Not significant

The treatment effect in respect of cane yield was significant only in the year 1945-46 out of five years when November planting yielded significantly higher than spring planting. But the loss in yield was compensated in increase of the recoverable sugar in the March planted crop. So that the resulting sugar yield differences in all the five years were not significant. Thus planting in November did not result in higher cane or sugar yield. This is evident from the combined analysis of the data for cane yields per cent recoverable sugar and sugar yield values of the crop.

2. *Varieties X periods of planting.* For indicating the effect of period of planting on the varietal performance the mean data for the five years period are given in Table VI as under :

TABLE VI

Effect of the periods of planting on varieties

Particulars	November planting		March planting		Mean	
	Co. 290	Co. 312	Co. 290	Co. 312	Co. 290	Co. 312
(*a*) Cane yields md./acre	517	533	501	545	509	539
(*b*) C. C. S. percentage of values	7·45	7·60	7·54	7·89	7·50	7·74
(*c*) C. C. S. yield md./acre	35·1	37·7	35·9	40·9	35·5	39·3
C. D. at 5 per cent	Not significant		Not significant		(*a*) Significant (*b*) Not significant (*c*) Significant	

The mean differences for the period of planting in relation to the varieties were not significant. The difference between the varieties of 30 md. was significant C. C. S. per cent values of the crop, contrary to the expectation, were higher for the March planted crop, the interaction being not significant. Varieties between themselves also did not show significant difference in C. C. S. per cent values. In sugar yield the difference between the varieties was again significant.

3. *Varieties X irrigation intervals.* The irrigation upto the end of germination was applied at weekly intervals. From May every year irrigation was applied (*a*) at weekly intervals and (*b*) at critical stage of soil moisture limit. The results are given as under :

TABLE VII

Response of varieties to differential irrigation (a) *Weekly interval,* (b) *critical stage of soil moisture*

Particulars	Variety Co. 290		Variety Co. 312		Mean	
	(*a*)	(*b*)	(*a*)	(*b*)	(*a*)	(*b*)
(i) Cane yield md.	542	476	547	531	545	503
(ii) C. C. S. percentage of value	7·29	7·71	7·75	7·72	7·52	7·71
(iii) C. C. S. yield md.	35·6	35·3	40·0	38·7	37·8	37·0
Critical difference at 5 per cent	Interactions not significant		Interactions not significant		(i) Significant (ii) Not significant (iii) Not significant	

The difference in cane yield due to irrigation interval for the five years period was 42 md. and this was significant. So that critical stage of soil moisture limit irrigation interval significantly decreased the yield. There was on the average an increase of 0·19 per cent in recoverable sugar. This augmented the total recoverable sugar per acre. Extra yield of 0·8 md. of sugar was not significantly in favour of weekly interval irrigation. This further confirmed the findings already reported [Raheja, 1944].

The interaction between varieties and irrigation intervals was not significant. On the whole the yield of Co. 290 with critical stage of soil moisure limit irrigation was depressed more than that of Co. 312, the difference in the two varieties being 66 and 16 md. respectively. The C. C. S. per cent values for the critical stage of soil moisture were the same in both the varieties. The difference in between the two irrigation intervals was apparent only in Co. 290 and not in Co. 312. In sugar yield the differences in favour of weekly irrigation interval in varieties Co. 290 and Co. 312 were 0·30 and 1·30 md. respectively. The interaction was not significant. Thus in both the varieties application of irrigation at critical stage of soil moisture limit resulted in saving of water applied to the crop.

Conclusion

The germination of majority of the buds planted in the month of November took place in the period March to April when the average daily temperatures were above 70°F. The temperature records have shown that minimum temperatures being below 45°F., the average daily temperatures even in November were below 70°F. In the subsequent months of December, January and February even the mean maximum temperatures in most of the years were below 70°F. In the germinated plants the suckering was retarded. As the suckering of the November planted crop took place at the same time as that of the March planted one the yield was not appreciably increased. March planted crop in fact gave as high per cent recoverable sugar if not more as the November crop. In view of these facts the practice of planting cane in November in Peshawar valley is neither beneficial due to higher outturn of cane nor higher sucrose in the cane crop. Besides, the planting of cane in November in the *shaftal* means loss of yield of fodder.

Variety Co. 312 performed better than Co. 290 on the average over a period of five years. The differences in cane and sugar yields were significant. The interaction between varieties and periods of planting was not significant. On the whole Co. 290 suffered less by November planting than Co. 312. The latter performed better by March planting. Khan and Raheja [1943] have already indicated higher susceptibility of Co. 312 to frost injury than Co. 290 and these findings support the observations recorded already.

Although the interaction between varieties and irrigation intervals was not significant, in cane yield Co. 290 suffered more by critical stage of irrigation application interval treatment. The sugar differences with respect to irrigation intervals in both the varieties were small. It follows from this that both the varieties should be given irrigation at critical stage of soil moisture limit to improve quality of cane

and reduce the expenditure on irrigation, particularly where water charges are paid on volumetric basis.

Summary

A complex experiment combining varieties, periods of planting and irrigation interval treatments was conducted for a period of five years. The objective of this experiment was to determine the effect of autumn planting and restricted irrigation supply on the crop with a view to obtain better quality and high sugar return per acre. The observations and data have revealed as under:

In November planting the germination occurs to a limited extent up to end of February, owing to temperatures being sub-optimal for germination. The best period of planting indicated is the month of March.

The cumulative growth in length of autumn planted crop is less. In November planting variety Co. 312 suffers more than Co. 290. This was reflected in early growth of the varieties.

In cane yield, recoverable commercial cane sugar and sugar yield the differences between November and March plantings were not significant. Fodder yield of *shaftal* crop in which cane was planted in November was reduced.

Variety Co. 312 significantly yielded higher than Co. 290 in cane and sugar outturn. The interaction between varieties and periods of planting was not significant. Mean sugar yields indicated less difference between November and March plantings in Co. 290 than in Co. 312, the differences being 0·8 md. and 3·2 md. respectively.

Weekly interval irrigation treatment gave significantly higher outturn of cane crop over critical stage of soil moisture limit treatment. But in sugar yield the difference was not significant owing to higher recoverable per cent commercial cane sugar. The interaction between varieties and irrigation intervals was not significant.

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RECENT PHYSIOLOGICAL INVESTIGATIONS ON DROUGHT RESISTANCE IN CROP PLANTS

By P. C. Raheja, Agronomist, Indian Agricultural Research Institute, New Delhi

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(With three text-figures)

UPTO the close of the first decade in the twentieth century most of the research workers believed that drought resistant plants transpire at a low rate and that their water requirements are small. This formed the basis for selection of crop plants for dry farmed areas and arid tracts. Such attempts at selection proved abortive and led to the realization that a thorough study of physiological characters associated with drought resistance should be carried out for the proper understanding of the problem which, without recourse to elaborate and expensive field trials extending over several years, would enable agronomists to select out new and valuable strains suitable to the arid environments.

Transpiration rate and drought resistance

Jost [1907], Warming [1909], Bakke [1914] and others held that the principal peculiarity of xerophytes is their ability to expend water scantily. On the contrary Maximov and Colleagues [1929] noticed that wild plants, which are capable of enduring prolonged drought maintain high transpiration rate so long as the soil moisture is readily available. The high intensity of transpiration exhibited by relatively drought resistant plants, according to Maximov, is not accidental but due to the fact that most of the factors that make for a dry habitat, namely, insolation, high wind velocity, deficient soil moisture, etc., provoke such changes in the body of the plant as enable them to maintain a high transpiration rate. The experiments of Alexendrov [1922], Frey [1924] and Kokin [1926] showed that foliage developed under conditions of impeded water supply possess higher intensity of transpiration than the one developed under conditions of liberal water supply.

Drought resistance and relative water requirements

Simultaneously, Briggs and Shantz [1914] in America and Maximov and Alexendrov [1917] in Russia determined water requirements of various cultivated crop plants and typical xerophytes as species of *Artemisia*, *Centaurea*, *Zagophyllum*, *Pegnum* and others. Independently they came to the conclusion that there did not exist 'direct proportionality between drought resistance and water requirement of plants'. Kiesselbach [1924] further investigated the problem and virtually came to the same conclusion.

Xerophytism and wilting coefficient of soil

Investigations of Briggs and Shantz [1912 and 1914] further showed that the lowest limit of available soil moisture for uninterrupted growth of plants, xerophytes

and mesophytes, is the wilting coefficient of soil, which is a physical constant dependent upon the physical nature of the soil. Evidence from the experiments of Livingstone and Colleagues [1920, 1926[1] and 1926[2]] and Wilson [1927] indicated that the critical content residue of soil moisture at the stage of wilting of plants showed a progressive increase in magnitude for a minimum index value for the sand to a maximum for the humus soil. Further investigations conducted by Veihmeyer and Hendrickson [1928], Capalmgam and Murphy [1930], Wadsworth and Das [1930] and Shaw and Sweezy [1943] have confirmed that under field conditions the conclusions of Briggs and Shantz [1917] substantially hold good.

Alway [1913] observed that under normal conditions plants are able to reduce the soil moisture to hygroscopic coefficient. The moisture available between the limits of wilting coefficient and hygroscopic coefficient has a very high value for the maintenance of life under conditions of extreme aridity. The independent investigations of Kiesselbach [1926] and Maximov [1929] further revealed that drought resistant plants have the peculiarity to utilize the water below the limit of wilting coefficient more economically by entering into a state of permanent wilting. This characteristic of drought resistant plants is not only possessed by different species and types of plants but also by different varieties of the same plant.

Leaf moisture saturation deficit and drought resistance

Investigations of Krasnose'sky. Maximov [1917] and Maximov and Krasnoselsky-Maximov [1924] indicated that more xerophytic plants are capable of sustaining 30 to 40 per cent loss of their total water content during the process of wilting. Bayles, Taylor and Bartel [1937] more recently worked on eight varieties of wheat and observed that grown with normal moisture the varieties Kubanka, Baart, Ones, Ceres, Marquis, Huston, Hope and Hope-Ceres indicated decreasing rates of water loss at Tucson, Pullman and Moro when exposed to drying for 52, 15 and 31 hours respectively. They noticed that the varieties indicating maximum deficit were less susceptible to drought and *vice versa.*

Xerophytes, osmotic pressure and biocolloids

Fitting [1911] noticed that xerophytes possess high osmotic pressure in their cells. Desert plants such as *Pegnum harmala, Rhus albida,* etc., which do not possess thick cuticle, hairy covering, sunkun stomata, etc., are found growing under arid conditions, have high osmotic value of their cell cap. Maximov, Dilanian and Silikova [1917] later confirmed these observations by independent studies. They noted that osmotic pressure were highest in xerophytes with extensive root system. Work of Harris, Gortner and Lawrence [1921] on hygrophytes, mesophytes and xerophytes also confirmed the conclusion that highest value of osmotic pressure of the cell sap is possessed by xerophytic plants, intermediate by mesophytes and lowest by hygrophytic plants. Keller [1925] experimentally demonstrated that high osmotic pressure of the sap retards desiccation of plants.

From the evidence adduced by Harvey [1918], Rosa [1921] and Newton [1924] relating to frost resistance and biocolloids Maximov [1929] inferred that these also

influence drought resistant capacity of the plants. In arriving at this conclusion he depended on the suggestive evidence of the work carried out by MacDougal [1920] and Tumanov [1927]. This inference of Maximov has since been confirmed by Newton and Martin [1930].

Recent observations

From the foregoing it is evident that several aspects of drought resistance particularly relating to the water balance in plants and dry matter production have been investigated, other aspects especially relating to the metabolism in plant in relation to drought resistance have not received the attention they deserve. In the following text an attempt has been made to summarise some of the observations on these aspects.

A. *Quiescent state of wilting*

Studies on drought resistance in cotton were taken up at Lyallpur [1932] and two varieties *Gossypium herbaceum* Punjab American Type 4F. and *Gossypium indicum* variety *Mollisoni* were selected for comparative study to determine the progressive rate of transpiration loss over a long period until complete desiccation occurred. These experiments were repeated a number of times. The comparative results are shown in Fig. 1. It will be observed that the *Mollisoni* (*Gossypium indicum*) type indicated very wide fluctuations in their rates of transpiration from day to day compared to that of the Punjab American variety. This was particularly so in the earlier days. The plants of *Mollisoni* cotton entered quiescent state of wilting about 22 days after the start of the experiments while the Punjab American variety entered the quiescent state of wilting within 13 days. In the former case the period of quiescent state of wilting was far prolonged than in the latter variety, in spite of the fact that almost same rate of transpiration was kept maintained during the stage of quiescence. This experimentally demonstrates that drought resistant type (*Mollisoni*) can endure a state of permanent wilting (Quiescent state) for a more prolonged period than the less resistant one.

B. *Water balance in the plant*

An interesting fact was noted about the leaf and stem moisture during the process of wilting. Samples of foliage and stem were collected from plants in pots at various stages of wilting. Side by side soil moisture was also determined. The results of leaf and stem moisture thus determined have been plotted against the per cent soil moisture (Fig. 2). It will be observed that above permanent wilting coefficient (4.0 ± 0.87) of soil a constant difference between per cent leaf and stem moisture is kept maintained. At the approach of permanent wilting and thereafter, the leaf and stem moisture tend to equalise and as further desiccation proceeds it is the stem which loses more moisture than leaves. From this it is evident that a marked equalization of stem and leaf moisture comes to exist during the quiescent state of wilting of plants. This obviously explains that when the forces of supply and demand for water in the cellullar units tend to balance 'at par' the quiescent state of wilting comes to exist. But such an equilibrium or balance for a longer

DESI COTTON
4 F Pb. AMERICAN COTTON
RATE OF TRANSPIRATION PER 100 SQ. CM. LEAF AREA IN GMS.
TIME INTERVAL PER 24 HOURS PERIOD

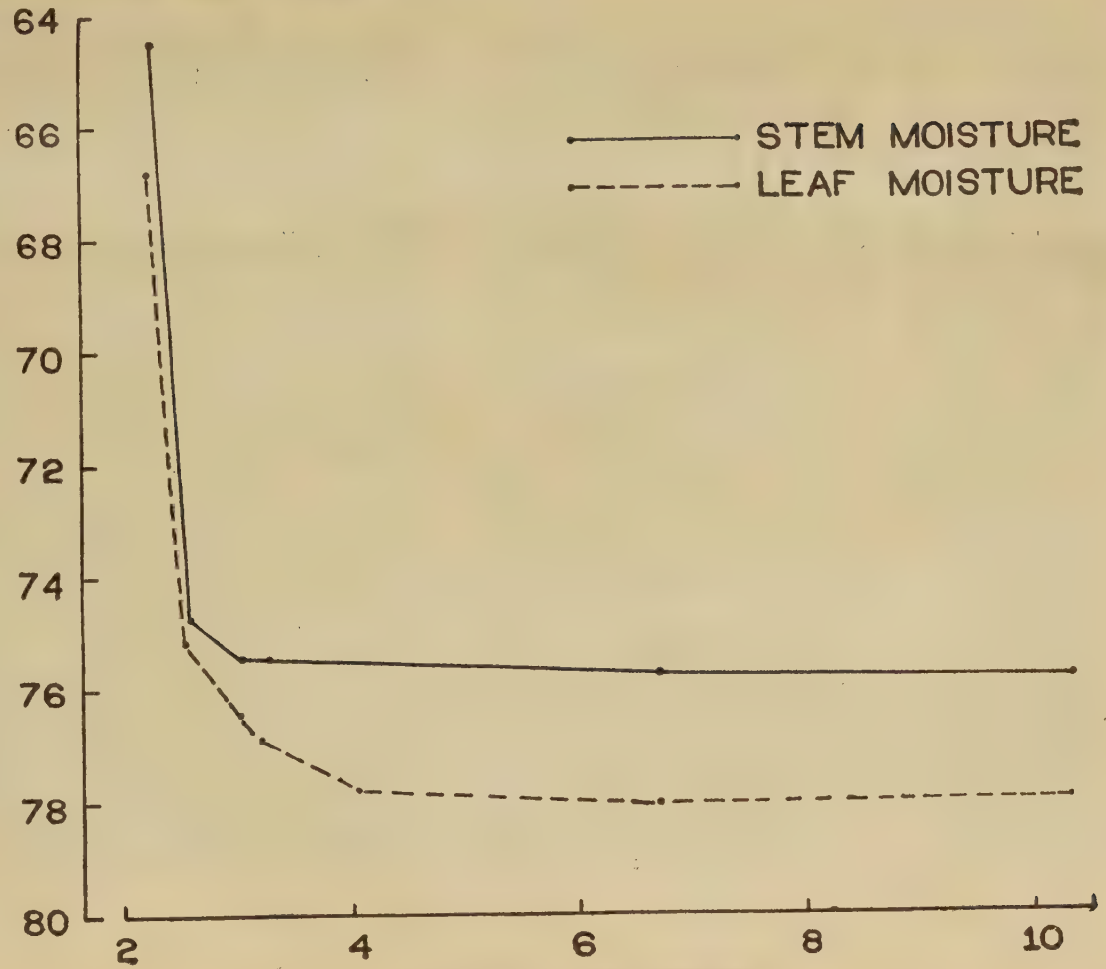

FIG. 2. Leaf and stem moisture in wilting plants

period can only exist if roots are able to draw upon the reserve stores of soil moisture from the sub-soil when scantily available moisture from the upper layers is exhausted.

Khanna and Raheja [1947] carried out studies on water relations of sugarcane plant. The various aspects studied were as under:

(i) Water content and diurnal moisture deficit in cane leaves;

(ii) Rate of water loss during the course of wilting;

(iii) Relative rate of transpiration from varieties during the hot weather period;

(iv) Relative transpiration rate of various varieties during the maturation stage of the crop.

These studies yielded valuable information on the phenomenon of drought resistance in varieties of sugarcane. It was observed that (*a*) the degree of saturation deficit in leaf moisture after the mid-day hours did not depend upon the degree of xerophily possessed by varieties but upon the osmotic value of the cell sap. Thus early maturing varieties, namely, Co.281, Co.299, Co.313 and Co.356 exhibited a higher saturation deficit after the mid-day hours than either the mid-season or late canes, *viz.*, Co.205, Co.285, Co.210 and Co.313, Co.326 and Co.331. The degree of saturation deficit was the maximum in autumn months and minimum during the monsoon season. (*b*) Irrespective of the degree of drought resistance of varieties the course of changes in the rate of water loss from the wilting leaves was *normal* [Knight, 1922] during the drought period of hot weather when soil moisture was continuously on the decrease in the soil at Pusa, North Bihar, and temperatures were on the increase and relative humidity, particularly during the mid-day hours, was very low.

(*c*) Another important fact noticed was that foliage-root ratios and the relative transpiration ratios of the varieties during hot weather and the autumn months, under conditions of drought in North Bihar, exhibited high significant correlationships between the two. These correlations revealed the great importance of root system in maintaining water balance under conditions of drought. Khanna [1934] conducted extensive studies on the root system of sugar cane varieties and classified the root system of sugarcane into three distinct types, namely, (i) mesophytic, (ii) semi-xerophytic and (iii) xerophytic. The classification is primarily based on the nature of vertical and horizontal spread of the root system in the soil. Discussing the results of the correlations between relative transpiration ratios and the foliage-root ratios the authors commented, 'The varieties with mesophytic type of root system are less resistant to drought owing to more of lateral spread, so that during the periods of drought the varieties suffer from low availability of water for maintaining water balance of the plant. During the hot weather (under rainfed conditions of North Bihar) and in the autumn months when the crop has to subsist on the conserved moisture in the soil, the type of root system must play very significant part in the upkeep of leaf moisture, rate of transpiration, turgor, etc. A variety which is unable to adjust itself under these environmental conditions must of necessity fail'.

C. *Habitat and respiration rate of plants*

(*a*) For the study of root respiration five varieties widely differing in their drought resistant character were selected by the author [1934]. Plants of these varieties showing normal growth were dug out and their root system were washed. Of the cleansed roots respiratory activity was determined in the laboratory. Five plants in each case were taken to estimate mean rate of respiration of each of the five varieties. The results are tabulated below :

TABLE I

Respiration rate of roots per gm. (fresh weight) in c.c's per hour

Varieties				
Co. 213	Co. 210	Co. 326	Co. 285	Co. 205
0·287	0·121	0·120	0·107	0·059

The data indicate that varieties Co.205 and Co.285 had lower rate of respiration compared to Co. 210 and Co. 326 and the latter two lower than Co. 213. This is as it was expected. Varieties having low respiratory activity have been observed as more drought resistant in the field.

Importance of the root system, especially of the vertical type, has already been stressed in the preceding section. In deeper layers, where supply of oxygen is available in limited quantities, low respiratory activity proves of great advantage to deeper penetration of the roots in the soil. The drought resistant varieties of sugarcane thus tend to meet the exigency of low oxygen content of the soil by a low rate of their root respiration and are able to carry on their life processes under reduced supply of oxygen and thereby enable the plant to subsist on the available sub-soil moisture during periods of drought. [Cannon, 1917 ; Cannon and Free, 1920 ; and Clements, 1921.]

(*b*) The hot weather conditions in North Bihar typically represent conditions of drought. Cane crop is planted in mid-February on the conserved soil moisture. The weather conditions continue to be arid while soil moisture is depleted by the cane crop. The rate of transpiration or, to state more precisely of evapo-transpiration, is very high from mid-April to mid-June. Varieties which are capable of limiting transpiration rate and maintaining high net assimilation rate prove more useful. Keeping up of high net assimilation rate depends upon higher rate of carbon assimilation and low rate of respiration in the plant. Therefore such plants as are capable of maintaining low respiration rate should prove of value under conditions of drought.

Under hot weather conditions of North Bihar studies on respiratory activity of seven varieties possessing characters of early, mid-season or late maturity and ability to resist drought were carried out by Khanna and Raheja [1938]. The

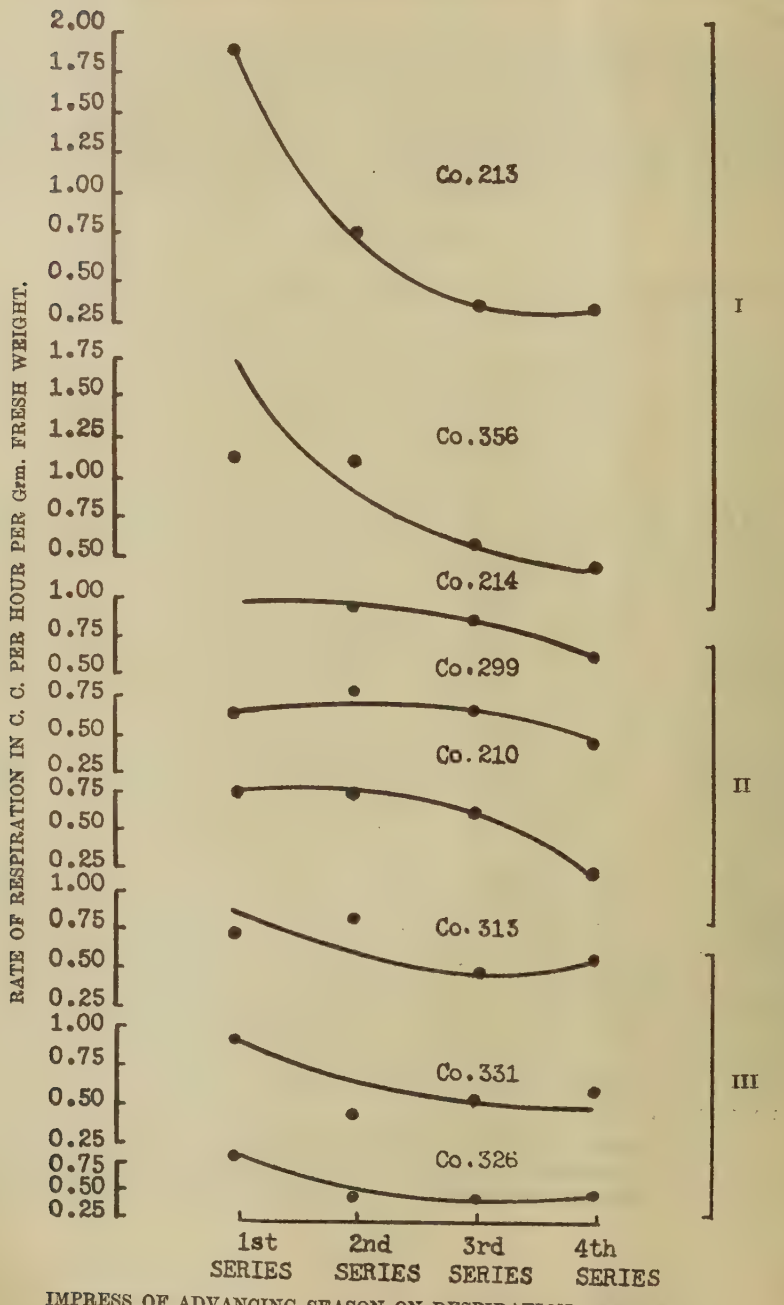

FIG. 3. Respiration of sugarcane *in situ*

results indicated that the impress of advancing season on the respiratory activity of varieties (Foliage) was evident (Fig. 3). Three distinct types of curves could be observed. In the first type the initial respiratory activity of the varieties Co.356 and Co.213 was high. A steep concave fall was noticed thereafter and the curve tended to flatten towards the end of the hot weather. In the second type of curve the fall was moderate and long delayed. Varieties Co.214, Co.299 and Co.210 indicated such a course of respiration. In the third type of curve a slight steep decline was followed by a moderate rectilinear course. The varieties which adopted such a course were Co.313, Co.331 and Co.326. These variations in the differential responses could not be regarded as dominated by one critical factor such as temperature but had to be viewed as resultant of complex of both environmental and edaphic factors and these definitely comprised conditions of drought for the varieties under test. The curves of the varieties, however, indicated a fair degree of relationship between the magnitude of depression in the respiration rate and the acknowledged drought resistance of the different varieties.

Similar studies on varieties Co.213, Co.331, Co.299, Co.313, Co.356, Co.419 and Co.421 were repeated at different periods during the critical stage in the hot weather [Khanna and Raheja, 1948]. Varieties Co.210 and Co.326 were substituted by varieties Co.419 and Co.421. Statistical analysis of the two seasons, data of the varieties Co.213, Co.299, Co.313, Co.331 and Co.356 indicated that the gross effect of seasons was not evident. But the differences amongst the respiratory activity values of the varieties were significant for the mean values of the two seasons. Thus critically the respiratory activity values were the same for varieties Co.213, Co.356 and Co.299. All the three had significantly higher rate of respiration compared to that of Co.313. Variety Co.299, however, alone had significantly higher rate of respiration compared to that of Co.331. Irrespective of the seasons, mean respiratory activity of all the varieties indicated decrease as time elapsed. It is significant to note that the interaction between varieties and periods in the matter of respiration was also observed to be significant, meaning thereby that varieties differed in their respiratory activity in relation to conditions of drought. Varieties Co.213 and Co.356 which are somewhat more drought susceptible cut down their respiration rate more rapidly than Co.313 or Co.331, the less drought susceptible ones. The differences were significant at one per cent level of significance. Thus the combined data for the two seasons confirmed the observation that under conditions of drought the rate of respiration decreased with the passage of time.

Resume. For crops to complete their life cycle normally under conditions of drought it is essential that (*a*) plants should be able to maintain favourable water balance in their above ground parts and (*b*) keep up high net assimilation rate under such adverse conditions. Recent observations have indicated that drought resistant plants enter into quiescent state of wilting as soil moisture decreases below the critical limit. A marked equalization of leaf and stem water content, in cotton, comes to exist during this quiescent state of wilting. Amongst varieties of sugarcane, cell sap of which contains higher content of sugars, the degree of saturation deficit in leaf moisture not only depended upon the degree of xerophily of the varieties but upon the osmotic value of the cell sap. High correlations between the

relative transpiration rate ratios and the foliage/root ratios of varieties during hot weather and the autumn months when drought conditions prevailed, were observed which indicated the importance of root system for the proper maintenance of water balance in the plant. It has been shown that drought resistant varieties have a low rate of respiration and thereby they are able to send down their roots vertically deep into the sub-soil to exhaust the conserved soil moisture. Drought resistant varieties were observed to have low respiration rate of their shoots when drought was less severe. They cut down their respiration to a small extent as the plants experienced drought. On the contrary the drought susceptible ones indicated the impress of the advancing hot weather and very appreciably reduced their respiration rate. It is thus that the less drought susceptible ones had high net assimilation rate in the favourable environment and could also keep it up in the drought period.

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Cowpeas No. 1

COWPEAS IN THE PUNJAB AND ITS IMPROVEMENT

By H. C. Malick, Fodder Botanist, Sirsa

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(With Plate XVIII)

COWPEAS (*Vigna catjung*), an important *kharif* legume, is grown primarily for forage and as soil restorative but seed of some of the varieties is also used for table purposes. It is cultivated only to a limited extent as compared with other *kharif* legumes such as *guara* (*Cyamopsis psoraliodes*) and *moth* (*Phaseolus aconitifolious*), for fodder in the Punjab, but its high nutritive value coupled with ease in culture and short growing period justified giving serious consideration to its improvement. The crop also occupies a secondary place to other *kharif* fodder crops such as jowar (*Andropogon sorghum*), Maize (*Zeamays*) and lucerne (*Medicago sativa*), but because it enables the *zamindars* to get nutritious green fodder early in the *kharif* season, when there is scarcity, it is of great value in the farm economy, particularly in the irrigated tracts.

The crop thrives best on medium loam soils but grows quite well on soil of low fertility. It is adapted to the same climatic conditions as maize but is superior to the latter in drought resistance and tolerance to heat. Sowing of cowpeas like other *kharif* crops extends from the middle of March to the end of July, while early sown *i.e.*, from mid-March onwards enables high yields of nutritious green forage to be obtained at a time when it is needed most ; Sowing carried out later in the season, in the middle of July, sets good seed. Twelve to fifteen seers seed is enough to sow an acre for fodder but five to six seers seed per acre ensures a good seed crop when sown in rows about 1½ ft. to 2½ ft. apart. Crop requires very little care after sowing except an irrigation or two before it is ready for harvesting as fodder. Usually crop is cut within 70 to 75 days after sowing when its first formed pods are about to ripen. On an average it yields 250 to 300 maunds of green fodder per acre.

Fodder is particularly rich in protein and is relished by cattle. In proper stage of its growth, when enough pods have formed, it is highly nutritious and enhances the flow of milk. Sowings, especially early ones, are usually done mixed with maize, with which its growing period synchronises, form a very balanced ration for livestock. In addition, cowpeas seed both green and ripe as well as its green pods are relished very much for culinary purposes. In view of these qualities, efforts were directed to make available some high fodder yielding variety for the Punjab cultivator. Cowpeas No. 1 a new variety was approved by the Department of Agriculture, Punjab Plate XVIII.

Piper [1937] reported that ease in culture and productivity have combined to make cowpea a valued forage in America. He described about half a dozen varieties, which gave good account of themselves in U. S. A. According to McKee and Pieters [1937], a very large number of varieties were recognized in the

U. S. A. and these had developed through several hundred years of natural hybridization and incidental selection rather than by any planned improvement programme. In addition to the introduction of varieties from abroad, work has been done by experimental stations in bringing existing varieties together for comparative tests which resulted in a more extensive use of superior varieties and an elimination of the inferior ones.

Material and method

Small samples of six varieties, *viz.*, *Arlington*, *Groit*, *Victor*, *Brabham*, *Pontiac* and *New Era* were obtained from U. S. D. A. and another sample from Poona in 1928. These were sown in May 1928 in rows 18 in. apart, keeping the same distance from plant to plant. The sowings were repeated in the years 1929-30 in rows 4½ ft. in order to study the behaviour of these varieties. Having isolated a new type in 1931 from among them, experiments to compare the yielding ability with other *kharif* legumes, were started in 1933 and continued till 1935. The *kharif* legumes with which comparisons were made, included the most common drought resistant crops of the province, *viz.*, *guara* and other legumes, *i.e.*, soyabeans and velvet beans.

The new type was a selection from the New Era variety. It showed well defined difference from the present type in some of its characteristics such as luxuriant growth, long vines, broad leaves, long pods of pale straw colour containing well developed bold and kidney shaped seeds having buff colour deeply sprinkled with blue speaks. It maintained these characters uniformly in the succeeding years and was therefore considered a mutation and designated as cowpeas No. 1. The seed was then multiplied and comparative fodder yielding tests were arranged in the following years.

The characteristics of the above six varieties as described by Piper [1937] and Mc Kee and Pieters [1937] are as follows :

1. *Victor.* It is the outcome of a cross between Groit and Brabham. It is characterised by its resistance to wilt and namentodes which usually do serious damage to cowpeas.

2. *Groit.* This is a cross between whippoor-will and New Era, the seed sharing the colouration of both parents, apparently superimposed on each other.

3. *Pontiac.* It is an early flowering variety with erect growing habit and small size of plant.

4. *New Era.* It is another early maturing variety with bushy habit of plant. The seeds are bold, rhomboidal in shape.

5. *Brabham.* This variety is also the result of a cross between Iron and whippoor-will.

6. *Arlington.* This variety is easily distinguished by its sub-reniform seeds which are buff marbled with brown.

7. *Poona.* It is easily recognized from its erect habit, dark green leaves and medium bold seed of red colour.

These varieties showed a great differential response to the climate of this province. *Pontiac, Arlington* and *Brabham* could not withstand the climatic conditions obtaining here and died without making any good growth. *Victor* and *New Era* grew well and set a few seeds. Poona also made good vegetative growth to start with, but failed to set good seed later. Cowpeas No. 1 was therefore selected for preliminary tests both with Poona variety, *kharif* legumes like *guara*, as well as with soyabeans, and velvet beans from 1931 to 1936.

Results and discussion

The preliminary comparison of two varieties of Cowpeas No. 1 and Poona were arranged in a regular randomised blocks experiments in 1931-32. Yields of green fodder per acre are given in Table I.

Table I

Showing yield of green fodder

Variety	Date of sowing	Size of plot	Yield per acre Md. Sr.	Harvesting	Percentage of yield
1. Poona	4—4—31	1/20th	272—18	6-6-31	100·0
2. Cowpeas No. 1	No. 1	..	286—22	..	105·1

Comparatively better performance of cowpeas No. 1 indicated its superiority over the other. It also withstood better the severe summer climate from April to June, which is a very hot and dry period in this province and when rainfall is an exception rather than the rule.

As a next step, its yielding ability was, therefore, compared with *guara*, an important local *kharif* legume, capable of making good growth both under dry and irrigated conditions. Comparisons were made in regular randomised block experiments for a period of two years, results of which are given in Table II below :

Table II

Showing the yield of green fodder per acre of cowpeas No. 1 and guara No. 2

Year	Size of plot	Replication Number	Variety	Yield of green fodder per acre	
1933—34	1/20th	5	1. Guara No. 2	247—8	
			2. Cowpeas No. 1	206—2	<·01
1934—35	1/20th	5	1. Guara No. 1	371—25	
			2. Cowpeas No. 1	396—30	<·01

The yields obtained showed consistently and very clearly the superiority of cowpeas No. 1 over *guara* No. 2. The former gave 3 to 20 per cent higher yield than the latter.

The fodder yielding ability of cowpeas No. 1 was also compared with other legumes, *viz.*, soyabeans and velvet beans both of which appeared promising new *kharif* legumes. The experiments were conducted for one year at the Fodder Research Station, Sirsa and for two years at other Departmental Agricultural Stations. The crop, sown at the normal sowing time, keeping 15 seers seed rate per acre, made very good growth and gave the following yields of green fodder mentioned in Table III.

TABLE III

Showing yield of green fodder per acre of cowpeas No. 1 and other legumes

Year	Station	Variety	Sowing time	Size of plot	Replication	Harvesting	Yield per acre	P
1934	Fodder Research Station, Sirsa.	Cowpeas No. 1	7-6-34	1/10th	4	28-8-34		
		Soyabeans.					369 304	<·01
		Velvet beans					303	
1935	Hansi	*Guara* (Local)	10-6-35	1/20th	6		145	
		Guara No. 2					185	<·01
		Cowpeas No. 1					374	
	Gurdaspur	*Chari* (jowar)	25-4-35	1/20th	7		482	
		Cowpeas No. 1					236	>·71
	Gurdaspur	Cowpeas (Local)	26-4-35	1/20th	6	1-8-35	275	
		Cowpeas No. 1					355	<·01
	Gurdaspur	Cowpeas (Local)	28-7-35	1/20th	6	21-9-35	159	
		Cowpeas No. 1					173	<·05
	Gurdaspur	Velvet beans	26-8-35	1/20th	6		53	
	Mountgomery	Cowpeas (Local)	4-4-35	1/10th	6	13-6-35	108 78	<·01
		Cowpeas No. 1					188	<·01
1936	Gurdaspur	Maize-cowpea	10-4-36	1/10th	6		87	
		Cowpeas No. 1					131	<·01
	Gurdaspur	Soyabeans	4-4-36	1/20th	7	16-6-36	42	
		Cowpeas					202	<·01
	Gurdaspur	Velvet beans	6-7-36	1/20th	7	8-9-36	53	
		Cowpeas					98	<·01
1937	Gurdaspur	Velvet beans	4-4-37	1/20th	7	13-6-37	206	
		Soyabeans					145	<·01
		Cowpeas					264	
	Gurdaspur	Velvet beans	5-7-37	1/20th		15-9-37	46	
		Soyabeans					19	<·01
		Cowpeas					89	

The yields of cowpeas No. 1 were significantly higher than either *guara* No. 2, soyabeans or velvet beans. It gave very high yields of 368 maunds and 375 maunds at Sirsa and Hansi under irrigation in the years 1934 and 1935 respectively. In fact cowpeas gave almost double the yield of *guara* at Hansi Agricultural Station in 1935.

Comparison of cowpeas with either soyabeans or velvet beans were extensively carried out at the Gurdaspur Agricultural Station primarily under dry farming conditions. Crops were sown both early in the season as well as in the mid season, *i.e.*, with the advent of rains. From the results of the trials carried out there, it was quite evident that cowpeas was superior to both soyabeans and velvet beans in fodder yield, but cowpeas No. 1 gave only 236 maunds of green fodder per acre in comparison with *jowar* which yielded 482 maunds per acre. Cowpeas No. 1 significantly outyielded velvet beans and soyabeans in all the eight tests. Not only it gave higher yield than local cowpeas, it outyielded soyabeans and velvet beans by a considerable margine at Gurdaspur and Montgomery.

Yields of green fodder were lower in late sowings as compared to early sowings; whereas cowpeas No. 1 yielded 355 maunds per acre as compared to 275 maunds per acre of cowpeas local in early sowing in 1935, it gave 173 maunds as compared to 159 maunds of local in late sowing. Similarly in 1937 in early sowing cowpeas No. 1 yielded 264 maunds as compared to 89 maunds in the late crop. But in all cases cowpeas No. 1 was marked by its good vegetative growth and consequent high fodder yield.

The data of yield and the period of growth of cowpeas No. 1 further showed conclusively that this was a quick growing variety and enable large quantities of green fodder to be obtained early in the *kharif* season. Except in 1935 where cowpeas No. 1 was compared with cowpeas local and was harvested after more than 90 days, No. 1 invariably became ready for fodder in 70 to 75 days, yielding large quantities of green fodder in a very short duration.

Selection of superior plants as the principal means of improving cowpeas was continued both for forage and seed. Since seed is an important article for human food, improvement of cowpeas from this aspect was also included in the improvement programme. As a result a number of other pure breeding strains, *viz.*, 6, 36, and 40 were evolved in 1936 and comparison of their yielding abilities were instituted from 1937 to 1943. Further another new type No. 2, which was considered to be very superior for human food, was included in tests from 1943 to 1949. Table 4 gives the summary of results of the experiments carried out during this period.

It will be evident from the results given in Table IV that of the varieties under tests, Nos. 6 and 36 also appeared promising for fodder in 1937. They were compared with No. 40 in 1938 which outyielded all the varieties by giving 301½ maunds of green fodder per acre. These experiments were continued till 1948-49. Results of these trials extending over a period of 10 years conducted at the Fodder Research Station, Sirsa showed that No. 40 was another superior variety, as compared with other varieties. This variety, however, could not replace No. 1 because of comparatively very low seed setting.

TABLE IV

Showing the fodder yield per acre of cowpeas varieties at the Fodder Research Station, Sirsa. (Green fodder in maunds and seers)

Year	Date of sowing	Size of plot	Replications	Date of harvesting	Local	Varieties				C. D. in md. and srs. per acre at 5 per cent
						FOS No. 1	FOS No. 6	FOS No. 36	FOS No. 40	
1937—38	19—5—37	1/30th	6	12—7—37	226—20	252—0	276—10	219—30	..	21—26
1938—39	16—5—38	1/30th	5	8—7—38	256—20	255—0	285—30	248—10	301—20	39—38
1939—40	12—4—39	1/40th	6	25—6—39	233—0	254—0	252—0	237—0	271—0	18—32
1940—41	2—4—40	1/40th	6	6—6—40	204—0	211—0	220—20	211—0	235—0	11—36
1941—42	28—4—41	1/80th	6	17—8—41	250—10	261—10	283—10	..	219—0	38—39
1942—43	11—4—42	1/60th	6	15—6—42	..	328—4	338—12	324—28	357—0	42—22
1943—44	7—5—43	1/120th	6	27—8—43	264—0	321—0	435—0	432—0	483—0	67—3
1944—45	9—6—44	1/100th	6	28—9—44	285—30	215—0	223—30	214—8	252—26	45—0
1945—46	23—5—45	1/100th	6	31—8—45	305—0	303—13	284—6	312—20	283—30	79—0
1946—47	29—5—46	1/100th	6	30—7—46	214—0	312—0	331—0	295—0	327—0	38—35
1948—49	26—4—48	1/74th	6	17—7—48	..	286—30	185—0	275—26	268—0	63—18

TABLE V

Showing the yield of seed in cowpeas

Year	Date of sowing	Size of plot	Replications	Date of harvesting	Varieties						C. D. in md. & srs. at 5 per cent
					No. 1	No. 2	No. 6	No. 7	No. 36	No. 40	
1940—41	..	..	..	..	..	..	..	10—15	..	..	..
1941—42	25—7—41	1/65th	6	17—10—41	..	..	..	6—36	..	..	..
1942—43	10—7—42	1/10th	6	30—11—42	10—3	..	10—3	12—19	8—26	9—12	2—0
1943—44	6—8—43	1/120th	6	4—11—43	1—35	6—0	1—35	11—10	..	..	2—20
1945—46	28—7—45	1/100th	6	19—12—45	16—16	7—14	16—10	7—38	13—36	13—24	2—36
1946—47	8—8—46	1/100th	6	12—12—46	2—7	6—18	2—8	5—18	0—36	1—6	1—19
1947—48	18—8—47	1/60th	6	4—12—47	4—18	..	..	1—28	2—36	4—13	1—39
1948—49	7—8—48	1/80th	6	6—12—48	2—15	..	6—20	7—5	1—10	2—20	1—36

Since cowpeas seed is highly preferred for table purposes and there is always a keen damand for an attractive bold seeded variety, efforts were directed to find out some high yielding variety which should conform to these requirements.

During the year 1940-41, a new strain No. 7 which had white seed with brown eye was evolved and included in the intervarietal tests. It yielded 10 maunds 15 seers, and 6 maunds 36 seers of seed per acre in 1940-41 and 1941-42 respectively.

Further, with a view to establish the superiority of No. 7 as a good seed yielding variety as compared to other fodder varieties, it was included in a comparison of Nos. 1, 6, 36 and 40 for seed yield. The yield of seed obtained in 1942-43 were very good and established No. 7 as a superior seed variety both from the stand of quantity and quality. It gave 12½ maunds seed per acre which was significantly higher than the yield of all other varieties. Trial carried out in the succeeding years also showed definitely that No. 7 was a good seed variety. The detail of seed are given in Table V.

Since no other variety could replace No. 1 for fodder, it was desired to make its seed available for extensive cultivation in the province. Studies with its seed setting were therefore continued. Apart from this, it enabled us to find out the effect of varying spacings on the yield of seed in cowpeas No. 1. Experiments to compare the three spacings, *viz.*, 1½ ft., 3 ft., and 4 ft. were started in 1942-43 and continued up to 1946-47 at the Fodder Research Station, Sirsa. The yields of seed obtained are given in Table VI.

TABLE VI

Showing the yield of cowpeas No. 1 under different spacings

Year	Date of sowing	Size of plot	Replication	Date of harvest	1½ ft.	3 ft.	4½ ft.	·05
1942-43	24-7-42	1/14th	4	3-12-42	10-33	11-33	13-9>	·03
1943-44	8-8-43	1/20th	8	18-11-43	1-20	1-20	1-20>	·05
1944-45	5-7-44	1/20th	5	28-11-44	6-30	8-7	9-16>	·05
1945-46	10-7-45	1/20th	5	29-12-45	16-28	15-39	17-9>	·05
1946-47	24-7-47	1/20th	5	11-11-46	7-34	9-0	8-30>	·05

It was evident that though some differences in yield of seed were observed in greater spacings, the differences were not significant indicating that greater spacings were not necessarily conducive to high seed yield in this variety.

The cowpeas plant gives out long vines which make up for the larger number of plants in small spacings, thus enabling almost equal yields of seed to be obtained in different spacings.

While very high seed yields were secured in 1942-43 and 1945-46, they were only moderate in 1944-45 and 1946-47. Yields were exceptionally low in 1943-44 because of the severe jassid attack to the crop. The insect infestation affected the growth of leaf and vines adversely. Leaf in particular remained very small in size and plant became very much stunted in growth.

TABLE VII

Showing characteristics of cowpeas varieties

Variety	Habit of plant	Size of leaf	Number of days taken to flower	Colour of flower	Pod habit	Pod colour	Pod length	Number of seeds per pod	Number of days taken to ripen	Colour of seed	Weight of 1000 seeds
No. 1	Semi-spreading.	Broad light green	51	Violet	Pendulous	Straw white inflated.	17·18	14	72	Bold buff with blue specked sprinkled.	131·13
No. 6	Semi-erect	Broad deep green	60	,,	Pendent	,,	14·64	15	76	Bold specked with green tinge.	118·7
No. 36	Spreading	Medium green	60	,,	Semi-erect	,,	14·64	12	72	Marbled bold	103·93
No. 40	Semi-spreading	Deep broad green	61	,,	Horizontal	,,	19·00	13	70	Buff with specks bold.	132·29
No. 2	Prostrate	Broad dark green	58	white with slight violet tinge.	Pendulous	Straw with yellow tinge.	18·66	10	70	Bold white with dark leaf.	157·00
No. 7	Semi-erect	Medium deep green	65	,,	Erect when green and Pendulous when ripen.	Straw white with brown eye.	11·68	9	81	Medium white	86·00

Before the conclusion of these studies, it seemed desirable to mention the characteristics of the various varieties that were evolved and have been under trial for the last so many years. In Table VII are described very precisely the characters of these varieties.

Taking into consideration the results of fodder and seed yield trials of various cowpeas varieties, it was evident that No. 1 was superior to other varieties because it gave high yields both of fodder and seed. No. 40 was another superior variety for forage production.

Both No. 2 and No. 7 are good seeders and their attractive white seed is very much liked for human food, but No. 2 on account of its bold and white seed is preferred. No. 7, however, gives higher yields of seed than No. 2.

Summary

Work on the improvement of cowpeas in the province has yielded very useful results. Cowpeas No. 1, a mutation is very heavy fodder yielding variety. It gives higher yield of forage as compared to *guara*, soyabeans and velvet beans.

Another variety No. 40 superior to No. 1 was evolved.

No. 2 and No. 7 are good varieties for human food but No. 2 on account of bold white seed is preferred.

Spacing of 1½ ft., 3 ft. and 4½ft. did not show significant difference in the forage production of cowpeas.

Varieties tested for fodder and seed have been described.

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THE ALGAL FLORA OF CERTAIN INDIAN SOILS*

By A. K. Mitra, Department of Botany, University of Allahabad

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VERY little information is available as to the nature of the algal flora of Indian soils. H .D. Singh [1933] studied the algae of the soils of Lahore, while Banerjee [1935] and R. N. Singh [1939] have worked on the algal flora of rice-fields. The first two authors have noted a marked preponderance of *Myxophyceae*, while R. N. Singh [1939] does not consider any blue-green alga to be an important member of what he regards as ' a widely distributed ecological plant formation in the paddy-field soils of the United Provinces'. None of the three Indian authors encountered any new species, although R. N. Singh recorded variants from the type in seven instances. On the other hand De [1939], working on a different problem, has recorded the presence of six *Myxophyceae*, four of them new species, from cultures of rice-field soils. Some work on the algae of cultivated soils in South India, has been carried out in Professor Iyengar's laboratory at Madras and a few new genera like *Heterothrichopsis* [Iyengar and Kanthamma, 1940, II] *Hormidiella* [Iyengar and Kanthamma 1940, I] and *Westiellopsis* [Janet, 1941] have been described. These records indicate that the soils of India harbour a rich algal flora comprising many new forms. The results obtained in the present investigation, which was undertaken to elucidate more fully the nature of the algal flora of certain Indian soils, amply justify this view. The nearly eighty species that have been identified from the sixteen samples of soils examined, include one new genus, fifteen new species, sixteen new varieties and a number of new forms. An attempt has also been made to correlate certain of the physical and chemical composition of these soils with their algal flora.

Collection of samples and method of study

The sixteen samples of soil studied are broadly of three kinds : (1) ordinary alluvial soil comprising uncultivated and cultivated samples, (2) alkaline or 'usar' soil and (3) red soil. The first two kinds were collected by the author within a radius of twenty miles of the city of Allahabad in the Uttar Pradesh, North India, while those of the third kind gathered from the neighbourhood of Madras, South India, were obtained through the kindness of Professor Iyengar.

Most of the samples were taken from the surface to a depth of 2 in. with a sterilized spatula. The soils from the deeper layers have not been examined, since it has been shown by Petersen [1935] and by Fritsch [1936] that the algae found there are washed down from the surface. Moreover, since many of the soils were collected from cultivated land, the distribution in depth of the algae would be influenced by agricultural operations. The algae of the ' usar ' soils have not been

*Work done at the Botany Department, Queen Mary College, London. Part of a thesis persented for the Ph. D. degree of the University of London.

studied and, in view of the peculiar nature of these soils, (*see* p. 366), it was thought advisable to enquire into the vertical distribution of algae in them. A steel plate, about six inches broad and one and a half feet long, was sterilized by swabbing in spirit and flaming. It was then driven vertically into the soil and a hole was dug adjacent to it. After removal of the plate a vertical face of soil was exposed. This was scraped with a hot scalpel at a depth of 8 to 10 in. and samples were collected by pushing a sterilized cork-borer, about 1 in. in diameter, horizontally into the soil at that level. The instruments were again sterilized and further samples were taken in a like manner from 4 to 6 in. depth. Finally samples were collected from the surface down to a depth of 2 in.

All the samples were transferred on the spot into wide-mouthed glass jars plugged with cotton-wool and previously sterilized in an autoclave. They were kept at room temperature (35°C.) and shaken occasionally without removing the plug. In about two weeks all the soils became quite dry. They were then packed in three successive paper bags which had been sterilized in the oven at 170°C. for three hours and taken to Professor Fritsch's laboratory where cultures were started. The soils remained in a desiccated condition for more than five months.

Enrichment cultures (liquid and moist) were prepared with De's [1939] modification of Benecke's solution† and also with pure pyrex-distilled water. Liquid cultures inoculated with 10 gm. of soil were set up in sterilized half-pint milk bottles filled to a depth of about 2 in. Their mouths remained plugged with cotton-wool and covered with paper. Moist cultures were prepared by spreading about 5 gm. of soil in sterilized petri dish which were periodically moistened with appropriate liquid. Both kinds of culture were prepared in triplicate. One culture of each set was kept at room temperature near a north-east window. A second set was placed in a lighted window box. The temperature inside the window-box varied between 20°C. and 25°C. while the light-intensity as measured with a photo-electric exposure meter was about half that of normal bright sunlight. The third cultures of each set was placed in an incubator with a glass top, like that used by De [1939]. It was lighted from above by seven 25-watt lamps, the light-intensity near the cultures being about one-third normal bright sunlight. The temperature within the incubator remained constant at 30° to 31°C. and the air inside was very humid so that tropical conditions with high temperature and humidity were realised as nearly as possible.

The soils from South India were not received until April and to obtain comparable results a second set of cultures of the Allahabad soils was prepared simultaneously with those of the S. Indian soils. Moreover, this time a further set of both liquid and moist cultures was prepared with pyrex-distilled water to which a small piece of cheese was added. It will be evident that in all, each of the soils from North India was studied in 26 cultures, while those from South India were studied in 14 cultures.

In connection with each set of cultures two sterile petri-dishes containing sterilized soil moistened with De's solution and pyrex-distilled water respectively,

†KNO_3—0·2gm., $MgSO_4$ $7H_2O$—0·2gm., K_2HPO_4—0·2gm. $CaCl_2$ $6H_2O$—0·1gm., $FeCl_3$ (1 per cent) —2 drops, water (Pyrex distilled 1000 c. c.)

were kept as controls, the lids being removed from time to time for a short period. None of these controls developed any algal growth.

List of soils and the algae that appeared upon them†

Soil 1. Wheat field, unmanured, with stubbles from previous crop, from Ramnathpur near Allahabad :

Chlamydomonas Iyengari, Coccomyxa subsphaerica var. *terrestre, Chlorococcum humicolum, Chlorochytrium*-sp. *Chlorella vulgaris, Pleurastrum terrestre* var. *indica, Hantzschia amphioxys* f. *capitata, Navicula minuscula, Phormidium tenue* var. *indica, P. molle, P. foveolarum, P. autumnale, Lyngbya nigra* var. *gelatinosa, L. Iyengari, L. rubida, Nostoc sphaericum, Calothrix membranacea, Scytonema ocellatum* (? var. *purpureum*) and *Fischerella mucicola* var. *indica.*

Soil 2. Wheat field, manured with cow-dung, with stubbles from previous crop, from Ramnathpur near Allahabad :

The algae that appeared in soil 1, with the addition of :—*Chlamydomonas eugametos* var. *indica, Chlorella botryoides, Ochromonas indica, Lyngbya aestuarii, L. rubida* f., *Oscillatoria formosa* f., *O. princeps, Microcoleus chthonoplastes, Nostoc paludosum* f., *Chlorogloea Fritschii* and *Campylonema lahorense* var. *allahabadii.* but lacking in : *Phormidium molle, Lyngbya Iyengari* and *L. rubida.*

Soil 3. Rice-field, dry for six months, unmanured, bare, from Siwait near Allahabad :—*Chlamydomonas Iyengari, C. grandistigma, C. eugametos* var. *indica, C. gloeogama, Coccomyxa subsphaerica* var. *terrestre, Chlorococcum humicolum, Chlorella vulgaris, Chlorochytrium* sp. *Dactylococcus bicaudatus, Pleurastrum terrestre* var. *indica, Protosiphon botryoides* f. *parieticola, Chloranomala palmelloides, Ochromonas indica, Hantzschia amphioxys* f. *capitata, Nitzschia* sp., *Navicula minuscula, Phormidium foveolarum, P. autumnale, P. corium* f. *terrestre,* P. *angustissimum* f., *P. Hieronymusii.* f. *major, P. ambiguum, P. allahabadii, Lyngbya aerugineo-coerulea* var. *terrestris, L. nigra* var. *gelatinosa, L. Iyengari* var. *violacea, L. rubida, L. Hieronymusii, Anabaena ambigua, Chlorogloea Fritschii, Chroococcus minutus* f., *Microcoleus chthonoplastes, Nostoc paludosum, N. sphaericum, Calothrix membranacea, Scytonema ocellatum* (?var. *purpureum*) and *Fischerella mucicola* var. *indica.*

Soil 4. Rice-field, as soil 3, but slightly manured with cow-dung.

The algae that appeared in soil 3 with the addition of : —*Carteria eugametos, Chamydomonas indica, Chlorella botryoides, Scenedesmus obliquus, Phormidium fragile* f., *P. tenue* var. *indica, P. molle, P. molle* f. *tenuior, Lyngbya Hieronymusii* var. *major, L. aesturaii, L. rubida* f., *Oscillatoria formosa* f., *Nostoc Linckia* var. *globispora, Anabaena allahabadii* and *Campylonema lahorense* var. *allahabadii* ; but lacking in :—*Chlamydomonas eugametos* var. *indica, C. grandistigma, Coccomyxa subsphaerica* var. *terrestre, Pleurastrum terrestre* var. *indica, Chloranomala palmelloides, Ochromonas indica, Chroococcus minutus* f., *Phormidium corium* f. *terrestre, P. ambiguum, Lyngbya Hieronymusii* and *L. rubida.*

† Systematic description of these algae will be found elsewhere. 13A

Soil 5. Rice-field, as soil 3, but irrigated being situated by the side of an irrigation canal.

The algae that appeared in soil 3, with the addition of :—*Chlamydomonas indica, Dictyosphaerium pulchellum* var. *minutum, Tetraedron pentaedricum, Oedogonium pusillum* var. *catenatum, Scenedesmus obliquus, Uronema terrestre, Spirogyra* sp. *Botrydium stoloniferum, Aphanothece saxicola, Chroococcus Westii* var. *terrestris, Phormidium molle* f. *tenuior, Lyngbya Iyengari, L. aestuarii, Campylonema lahorense* var. *allahabadii* and *Calothrix catenata*, but lacking in : —*Chlamydomonas grandistigma, Ochromonas indica, Phormidium corium* f., *terrestre, P. angustissimum* f., *P. Hieronymusii* f. *major, P. ambiguum, P. allahabadii, Lyngbya aerugineo-coerulea* var. *terrestris, L. nigra* var. *gelatinosa* and *L. Iyengari* var. *violacea.*

Soil 6. Rice-field, as soil 5, but slightly manured with cow-dung.

The algae that appeared in soil 5, with the addition of : —*Carteria eugametos, C. intermedia, Gonium pectorale, Chlorella botryoides, Dactylococcus bicaudatus* var. *curta, Scenedesmus prismaticus, Stigeoclonium* sp., *Ochromonas indica, Phormidium molle, P. tenue* var. *indica, P. fragile* f., *P. Hieronymusii* f. *major, P. ambiguum, Lyngbya rubida* f., *L. Hieronymusii* var. *major, Oscillatoria princeps, O. formosa* f., *Anabaena allahabadii, Nostoc paludosum* var. *major, N. Linckia* var. *globispora* and *Calothrix anomala*, but lacking in : —*Chloranomala palmelloides, Chlorogloea Fristchii, Lyngbya rubida, L. aestuarii* and *L. Hieronymusii.*

Soil 7. Garden soil, manured with compost, Botanical gardens, University of Allahabad.

The algae that appeared in soil 2, with the addition of :—*Chlamydomonas glocogama, Chloranomala palmelloides, Aphanothece saxicola, A. bullosa, Gloeocapsa decorticans, Phormidium rubroterricola, P. augustissimum* f., and *Lyngbya Iyengari*, but lacking in :—*Coccomyxa subsphaerica* var. *terrestre, Chlorella botryoides, Oscillatoria princeps, Phormidium tenue* var. *indica, Lyngbya nigra*, var. *gelatinosa* and *L. aestuarii.*

Soil 8. Uncultivated ground, bare, from Muirabad near Allahabad.

Chlamydomonas grandistigma Chlorococcum humicolum, Coccomyxa subsphaerica var. *terrestre, Chlorella vulgaris, Chlorochytrium, Pleurastrum terrestre* var. *indica, Hantzschia amphioxys* f. *capitata, Navicula minuscula, Phormidium fragile* f., *P. corium* f. *terrestre, P. molle, P.* sp. (? *usterii*), *P. autumnale, P. foveolarum, Lyngbya Iyengari, L. Iyengari* var. *violacea, Nostoc sphaericum, Calothrix membranacea, Scytonema ocellatum* (? var. *purpureum*) and *Fischerella mucicola* var. *indica.*

Soil 9. Red soil, uncultivated, from Vandalur near Madras.

The algae that appeared in soil 8, with the addition of :—*Chlamydomonas Iyengari, Chloranomala palmelloides, Protosiphon botryoides* f. *parieticola, Synechococcus cedrorum, Microcoleus chthonoplastes, Crinalium magnum, Phormidium angustissimum* f., *P. uncinatum, P. tenue* var. *indica, P. Hieronymusii* f. *major, Nostoc paludosum* f., and *Lyngbya aestuarii*, but lacking in :—*Chlamydomonas grandistigma, Coccomyxa subsphaerica* var. *terrestre, Navicula minuscula, Phormidium molle*, P. sp. (? *usterii*), *P. corium* f. *terrestre* and *Lyngbya Iyengari* var. *violacea.*

TABLE I

Numbers of Species of the different classes in the surface layers of the various soils

Soil number	Wheat soils				Rice-field soils						Garden soil	Uncultivated soil	Red soils				'Usar' soils				Totals	
	1	2	Total number of species	Average percent of species	3	4	5	6	Total number of species	Average percent of species	7	8	9	10	Total number of species	Average percent of species	11	14	Total number of species	Average percent of species	Total species of all soils	Average percent of species*
Myxophyceae	11	16	19	28	22	27	20	29	40	50	18	12	17	15	20	33	10	15	16	25	49	37
Chlorophyceae	6	8	8	25	12	11	18	24	26	58	9	6	7	3	7	18	3	6	6	16	28	32
Diatoms	2	2	2	66	3	3	3	3	3	100	2	2	1	1	1	33	0	1	1	16	3	66
Xanthophyceae	0	0	0	0	0	0	1	1	1	50	0	0	0	0	0	0	0	0	0	0	1	20
Chrysophyceae	0	1	1	50	1	0	0	1	1	50	1	0	0	0	0	0	0	0	0	0	1	20
Total	19	27	30	28	38	41	42	58	71	54	30	20	25	19	28	54	13	22	23	21	82	175

*Average of the number of species that appeared in various cultures of the group of soil expressed as percentages of the total number of species in all the soils.

Soil 10. Red soil, lateritic, uncultivated, from Red Hills near Madras.

The algae that appeared in soil 9, with the addition of :—*Phormidium molle*, *Lyngbya aerugineo-coerulea* var. *terrestris* and *L. Iyengari* var. *violacea*. but lacking in :—*Chlamydomonas Iyengari*, *Chlorochytrium*, *Chloranomala palmelloides*, *Protosiphon botryoides* f. *parieticola*,*Synechococcus cedrorum*, *Crinalium magnum*, *Phormidium tenue*, var. *indica*, *Lyngbya aestuarii* and *Nostoc paludosum* f.

Soil 11. 'usar' soil. Surface—2 in. from Siwait near Allahabad.

Chlorococcum humicolum, *Coccomyxa subsphaerica* var. *terrestre*, *Chlorella vulgaris*, *Microcoleus chthonoplastes*, *Phormidium foveolarum*, *P. autumnale*, *P. molle*, *P. molle* f. *tenuior*, *P. angustissimum* f., *Lyngbya aerugineo-coerulea* var. *terrestris*. *L. nigra* var. *gelatinosa*, *Nostoc sphaericum and Scytonema Hofmanni*.

Soil 12. Same soil as 11, but from 4 to 6 in. depth. *Phormidium foveolarum*, *P. molle*.

Soil 13. Same soil as 11, but from 8 to 10 in. depth.

The algae that appeared in soil 12.

Soil 14. 'usar' soil, partially reclaimed by cow-dung but no crop yet grown on it, surface 2 in. from Siwait near Allahabad.

The algae that appeared in soil 11, with addition of :—*Chlamydomonas indica*, *Chlorochytrium*, *Chloranomala palmelloides*, *Hantzschia amphioxys*, f., *capitata*, *Oscillatoria formosa* f. *Phormidium molle* f. *tenuior*, *P. corium* f. *terrestre*, *Lyngbya Iyengarii*, *L. rubida*, *Calothrix membranacea* var. *purpurea* and *Fischerella mucicola* var. *indica*, but lacking in :—*Lyngbya nigra* var. *gelatinosa*.

Soil 15. Same soil as 14, but from 4 to 6 in. depth.

The algae that appeared in soil 12, with the addition of :—*Chlorella vulgaris*, *Chloranomala palmelloides* and *Phormidium autumnale*.

Soil 16. Same soil as 14, but from 8 to 10 in. depth.

The algae that appeared in soil 13, with the addition of :—*Chlorella vulgaris*.

Chemical and mechanical analyses of the soils.

The results of chemical and mechanical analyses of the various soils are set forth in Tables II and III. The *p*H values were determined electrometrically using glass electrodes and boiled pyrex-distilled water. The determination of hygroscopic moisture and mechanical analysis of the soils were carried out according to the standard methods given in Robinson [1932] and Wright [1939] ; carbonate content was determined with the help of a Collin's [1906] calcimeter, while the exchangeable calcium was determined by Hissink's method [Wright, 1939]. Total nitrogen and total carbon were estimated by the modified Kjeldahl's method recommended by Robinson, Mclean and Williams [1929].

Consideration of the algal growth on the soils.

(*a*) *The general composition of the algal flora.* In all the soils, irrespective of their nature, the *Myxophyceae* show an overwhelming preponderance over the

TABLE II

Chemical constitution of the soils examined

Number of soil	*p*H	Percentage of carbonate	Percentage of exchangeable calcium	Percentage of total nitrogen	Percentage of total carbon	C/N ratio
1	7·71	0·424	0·415	0·0359	0·4198	11·7
2	7·53	0·614	0·542	0·054	0·5598	10·3
3	8·07	0·308	0·404	0·0437	0·4935	11·3
4	8·01	0·512	0·517	0·0529	0·5399	10·2
5	8·25	0·621	0·398	0·0413	0·3905	9·4
6	7·8	0·651	0·560	0·0519	0·5046	9·7
7	8·02	0·471	0·537	0·0525	0·5516	10·5
8	7·27	0·359	0·314	0·0312	0·38	12·2
9	7·4	0·248	0·068	0·0296	0·4203	14·2
10	7·2	0·176	0·055	0·0236	0·2639	11·2
11	10·02	3·463	0·035	0·0216	0·212	9·8
12	10·06	3·458	0·035	0·0144	0·1307	9·1
13	10·06	2·755	0·033	0·0151	0·1377	9·1
14	10·04	4·685	0·042	0·0 96	0·2986	10·1
15	10·04	4·707	0·032	0·0171	0·1526	8 9
16	10·03	3·975	0·034	0·0173	0·1591	9·2

TABLE III

Mechanical analyses of the soils examined

Number of soil	Percentage of hygroscopic mo sture	Per-centage of stone	Percentage of coarse sand	Per-centage of fine sand	Per-centage of silt	Per-centage of clay	Percentage of loss by solution
1	1·75	0·06	0·61	62·65	20	14	0·55
2	1·75	0·02	0·65	68·25	16	14	0·30
3	1·50	0·05	0·54	57·8	21	15	0·64
4	2·0	0·01	0·65	52·9	27	18	0·81
5	2·25	0·01	0·46	50·3	29	20	0·56
6	2·25	0·02	0·28	54·7	26	18	0·55
7	2·25	0·01	0·43	53·1	27	19	0·70
8	1·75	0·5	0·63	61·2	29	15	0·35
9	2·25	17·6	26·2	15·7	30	27	0·91
10	2·25	28·5	35·5	18·0	18	25	1·20
11	1·5	0·5	0·4	68·05	18	12	0·65
12	2·25	0·01	0·61	58·5	21	15	0·45
13	2·25	0·02	0·45	60·1	20	16	0·35
14	2·25	0·02	0·60	60·0	24	15	0·53
15	2·0	0·05	0·54	55·3	22	17	0·55
16	2·0	0·03	0·53	56·2	24	17	0·43

other classes, usually more than half the total number of species found belonging to this group (Table I). Even the average percentage of species of *Chlorophyceae* that appeared in the various cultures of soils is only 32, as compared with 37 for the

Myxophyceae. Three species of diatoms are at all common, the remaining diatoms present being occasional in their occurrence and never becoming sufficiently common to admit of their determination. Another noteworthy feature about these soils is the almost total absence of *Xanthophyceae*, *Botrydium* being the only genus found and that only in two of the soils from rice-field. The *Chrysophyceae* are represented only by *Ochromonas indica*, found in cultures of four of the soils.

(*b*) *Algal growth on the soils under various conditions of culture.* None of the soils bore any visible growth at the time of collection because of the prevailing dryness due to the high temperature and insolation to which they had been exposed although all of them showed the presence of algae after culturing. The time elapsing between the commencement of culture and the visible appearance of algae in a given soil varied somewhat according to the conditions. Growth appeared soon in the cultures kept in the incubator, and in most of the cultures of soils 1 to 7 the first signs were observable within ten days. The earliest algal growth was composed mainly of *Myxophyceae*, consisting especially of species of *Phormidium* (*viz. P. foveolarum*, *P. autumnale* and a few narrower species which did not appear so regularly) and of *Microcoleus chthonoplastes*. The only green alga associated with these was *Chloroccocum humicolum*. The *Myxophyceae* in question have a thin sheath and are not known to form any special resting stages, so that they must have developed from persisting filaments that had survived the drought and on advent of moisture had multiplied by hormogones. *Chlorococcum humicolum* possesses the faculty of rapid multiplication by swarmers. The early appearance of these algae together with the fact that they were present in almost all the cultures of the different soils indicate that they were present in abundance in the samples collected. The cultures were maintained for about a year and a half and during the later period the growth consisted mainly of species of *Phormidium*, *Lyngbya* and the larger *Myxophyceae* like *Fischerella*, *Calothrix*, etc., while the *Chlorophyceae* were crowded out and most of them formed resting stages. The spécies of *Chlamydomonas* were rather erratic in their occurrence, and the same species was found at various periods in different soils or even in the same soil [James, 1935].

Apart from the earlier appearance of growth in the cultures placed in the incubator, other differences were observed between them and the cultures kept in the window box or at room-temperature, and these differences became more pronounced with time. Certain species like *Scytonema Hofmanni*, *Oscillatoria princeps*, *Phormidium ambiguum*, *Synechococcus cedrorum* and *Aphanothece saxicola* as well as most of the forms with a coloured sheath or with coloured cell-contents (*viz. Chroococcus Westii* var. *terrestre*, *Lyngbya Iyengari* var. *violacea*, *L. rubida*) were confined to cultures kept in the incubator.

In the long run, however, the conditions in the incubator proved unfavourable, even for the *Myxophyceae*, and after about seven or eight months their cells showed a large proportion of degenerating cells which began to turn yellow.

Many of the *Chlorophyceae*, on the other hand, were encountered in cultures kept in the window-box or at room-temperature. The diatoms behaved like the *Chlorophyceae*, and only *Nitzschia* sp. was at all common in culture kept in the incubators.

The growth in the incubator with its abundance of *Myxophyceae* and comparative paucity of *Chlorophyceae*, is similar to that found in nature in the tropical soils for most of the year. In the hot humid months of the rainy season extensive growths of *Myxophyceae* are observed on the surface of the soil and although *Chlorophyceae* are present, they do not flourish. With the passing of the hot humid conditions, *Myxophyceae* become less abundant and the *Chlorophyceae* come to the front as is evident by cultures kept at room temperature while as the temperature again rises they are succeeded by *Myxophyceae*. This sequence, first observed by Fritsch [1907], in the rice-fields of Ceylon, holds good also for those of India and occurs also in other soils though less marked owing to the drier conditions.

The cultures to which a small amount of cheese had been added and which became rather foul, were peculiar in many respects. The number of species in all the soils thus treated, was severely restricted, but those present reached a degree of abundance not met with in the other cultures. These are species for which compounds from degenerating organic substances constitute the most suitable source of supply of nutrients. Most of these soils produced only *Phormidium foveolarum*, *P. autumnale*, *Chlorococcum humicolum*, *Pleurastrum terrestre*, var. *indica* and a very luxurious growth of *Chlorella vulgaris*. *Chlamydomonas eugametos* were common in most of the cultures with cheese but failed to appear in any of the cultures with other media. *Scenedesmus prismaticus* was also restricted to cheese cultures.

John [1942], expresses the opinion that liquid cultures do not give a true picture of the soil algal flora since they would admit of the growth of the dormant wind-borne spores of hydrophytic species. This might be said about many soils although sun and high temperature would kill most of the spores falling on the surface, but the conditions in liquid cultures resemble those in the rice-fields which are covered with standing water for about three to four months, during which there is an abundant growth of algae, in the subsequent dry period they may continue to vegetate in the deeper layers of the soil, although the majority probably persist as resting stage. Liquid cultures, therefore, proved valuable for the study of the algae of rice-field soils, and forms like *Dictyosphaerium pulchellum* var. *mintum*, *Oedogonium pusillum* var. *catenatum*, *Scenedesmus prismaticus*, *Uronema terrestre*, *Gonium pectorale*, *Chalmydomonas eugametos* var. *indica* and *Nostoc Linckia* var. *globispora* were common only in such cultures.

(*c*) *Algal growth on different soils.* Certain species appeared in almost all the cultures of the different soils and seem to constitute a community which is practically always present. These are *Chlorococcum humicolum*, *Chlorella vulgaris*, *Phormidium foveolarum* and *P. autumnale*. These are also some of the species that appeared first in the cultures, which indicate that they were present in abundance.

(i) Algae of the wheat field soils (1 and 2). The wheat field soil 2 which had a higher percentage of exchangeable calcium and total nitrogen and carbon (Table I) than soil 1, differed mainly in the presence of *Microcoleus chthonoplastes*, *Oscillatoria formosa* f., *Chlorogloea Fritschii*, *Lyngbya rubida* f., *Nostoc paludosum* f., and *Ochromonas indica*. These species seem to have a preference for the rich soils,

as most of them were either poorly represented or altogether absent from soils deficient in organic matter and exchangeable calcium.

(ii) Algae of the rice-fields (soils 3 to 6). The rice-fields are a unique, artificial but very ancient type of habitat without any direct parallel in temperate regions [Fritsch, 1939]. Although the physical and chemical constitution of the particular soils studied do not differ markedly from that of the other cultivated soils, many of the species recorded in this paper were found only in these soils. Moreover, of the 31 new species and varieties described in this paper, 14 were restricted to the rice-fields.

(iii) Algae of the garden soil no. 7. This soil which was similar in composition to those considered under (i) and (ii), contained many algae in common with them and in part confined to the three kinds of soil. *Aphanothece bullosa*, *Gloeocapsa decorticans*, and *Phormidium rubroterricola* were found only in the garden soil.

(iv) Algae of the uncultivated soils (8-10). These were all deficient in exchangeable calcium and total nitrogen and carbon, features correlated with a paucity of algal growth. Apart from the species already mentioned as being universally present, the only ones commonly met with in the uncultivated soil 8 from North India were *Phormidium molle*, *P. fragile f.*, *Coccomyxa subsphaerica* var. *terrestre* and *Scytonema ocellatum* (? var. *purpureum*), the last as well as moss protonema being present in this soil in much greater abundance than in any other. The red soils from South India (nos. 9 and 10) contained a much larger proportion of coarse sand and stone and less carbonate than the uncultivated soil from North India. *Synechococcus cedrorum* and *Crinalium magnum* were found only in the red soil.

(*e*) Algae of the 'usar' soils (nos. 11-16). The algae of the 'usar' soils differ from the others in having a higher *p*H and a higher carbonate content, coupled with low, total carbon and nitrogen. These are usually sodium soils in which the carbonate is chiefly in the form of sodium salt and they also contain a high proportion of sodium sulphate and sodium chloride [Dhar and Mukerji, 1936]. The scanty algal growth agrees with the lack of higher vegetation on these soils. The only members of the *Chlorophyceae* observed in the undisturbed 'usar' soil no. 11 were *Chlorella vulgaris*, *Coccomyxa subsphaerica* var. *terrestre* and *Chlorococcum humicolum* and even these were very infrequent. The *Myxophyceae*, which have a liking for alkaline media [John, 1942], were somewhat better represented. Thus *Microcoleus chthonoplastes*, *Phormidium foveolarum*, *P. autumnale*, and to a lesser extent *Nostoc sphaericum*, were rather common and *Calothrix membranacea* var. *purpurea* was restricted to 'usar' soil but only appeared in a few out of fifty-two cultures from the surface samples so that the last cannot be regarded as a regular constituent of the algal flora of this kind of soil.

Soil 14, which had been partially reclaimed by addition of cow-dung but on which no crop had yet been grown, showed a higher proportion of exchangeable calcium and total nitrogen and carbon and yielded a larger number of forms. *Chlamydomonas indica* and *Chlorochytrium* were observed in addition to the green algae

occurring in unreclaimed soil; there were also present species characteristic of cultivated soils, such as *Oscillatoria formosa*, *Lyngbya rubida*, *Chloranomala palmelloides* and *Hantzschia amphioxys* f. *capitata*, though these were far from being abundant.

Samples from the deeper layers of ' usar ' soil (12, 13) afforded only a scanty growth of *Phormidium foveolarum* and *P. molle* and this only in a few of the cultures. This can be related [Fritsch 1936 ; Petersen 1935] to the fact that ' usar ' soil is highly impervious to water [Dhar and Mukerji, 1936].

(*f*) *Effect of irrigation.* The largest number of species (58) was encountered in soil 6 from a manured and irrigated rice-field while sample 5 from an irrigated but unmanured field yielded the next largest number (42). Both soils were collected from plots adjacent to an irrigation canal and, although the surface appeared quite dry, there was some moisture below the surface owing to percolation from the canal. These soils, therefore, harboured several forms like *Chroococcus westii* var. *terrestris*, *Calothrix anomala*, *Dictyosphaerium pulchellum* var. *minutum*, *Oedogonium pusillum* var. *catenatum*, *Uronema terrestre*, *Spirogyra* spp. and *Botrydium stoloniferum*, which were not encountered in the unirrigated rice-field soils. It is, however, possible that some of the rarer hydrophytic forms like *Gonium pectorale*, *Tetraedron pentaedricum* and *Carteria intermedia* were carried into the soil with seepage water from the canal.

(*g*) *Effect of manuring.* Manuring has the effect of increasing the proportion of *Myxophyceae* to that of *Chlorophyceae*, as will be seen by comparing soil 2 with soil 1, soil 4 with soil 3, soil 6 with soil 5, and soil 14 with soil 11. Certain species like *Oscillatoria formosa* f., *O. princeps*, *Lyngbya Hieronymusii* var. *major* and *Anabaena allahabadii* appeared only on manured soils.

Comparison with the results obtained by other workers on Indian soil algae

H D. Singh [1933] examining cultures of 15 samples chiefly of fresh soils from Lahore, found 29 species of *Myxophyceae*, 4 spp. of *Chlorophyceae* and about 12 spp. of diatoms. The only species common to the Lahore and Allahabad soils are *Chroococcus minutus*, *Phormidium foveolarum*, *P. autumnale* (=? P. *uncinatum* of Singh), *P. ambiguum* and *Nostoc sphaericum*. He also mentions the occurrence of undetermined species of *Fischerella*, *Calothrix*, *Scytonema* and *Chlorococcum*, representatives of all of which were found in the present investigation as also species of *Aphanothece*, *Oscillatoria*, *Anabaena* and *Nitzschia*. It would seem, therefore, that these various algae may be widespread in Indian soils. Singh records a large number of diatoms but since he does not mention the particular soil in which they occurred, it is impossible to compare their distribution.

From desiccated soils Singh obtained only forms of *Oscillatoria*, *Phormidium*, *Anabaena*, *Nostoc* and diatoms, although neither the species nor the kind of soil are stated. My investigations which were carried out on desiccated soils only have disclosed the presence of a much larger number of species. Both they and Singh's results demonstrate the great preponderance of *Myxophyceae* over the representatives of other classes, and the almost entire absence of *Xanthophyceae*. Banerjee [1935]

examining desiccated and fresh samples from rice-fields again obtained 9 species of *Myxophyceae* as contrasted with only one member of the *Chlorophyceae ;* no diatoms were observed. In this connection it may be mentioned that Bristol [1920] has noted that soils possessing a rich blue-green flora contain only few species of diatoms.

On the other hand Singh, R. N. [1939], examining cultures from desiccated rice-field soils from four different localities records 17 *Chlorophyceae* and only 14 *Myxophyceae* ; he also found 12 species of diatoms. He concludes that in the rice-fields of the United Provinces there is a widely distributed algal community the most important members of which are *Chlorella vulgaris*, *Trochiscia reticularis*, (although found in only one sample from a depth of 2 in), *Gongrosira terricola*, *Oedogonium intermedium* and *Protosiphon botryoides* f. *parieticola*. It is noteworthy that this list does not contain any member of the *Myxophyceae*. Only five of the 43 algae recorded by Singh have appeared in my cultures of rice-fields, while 13 genera in his list are lacking in mine and 21 genera from mine are wanting in his list. Even such widely distributed species as *Phormidium foveolarum*, recorded by De [1939] and Holsinger [1935] from rice-fields of Bengal and Ceylon respectively and found abundantly in the Allahabad soils, did not appear in Singh's cultures.

The rice-field soils studied by me were collected from the same Province as that of Singh and the striking differences in their flora are surprising. Some of these differences may be due to the time of collection of the soils, to the extent of desiccation and also to the conditions of culture. However the differences suggest that far more extensive studies on rice-fields will have to be undertaken before the nature of the algal flora of this distinctive habitat can be determined.

Comparison of the Indian soil algae with those of temperate regions

Very little is yet known of the soil algal flora of the tropics, but the following comparison may, however, be made. The species *Chlorella vulgaris*, *Chlorococcum humicolum*, *Phormidium foveolarum* and *P. autumnale* have been repeatedly recorded from many kinds of soils in various parts of the world and seem to be regular constituents of the soil-flora throughout the globe. A similar wide geographical distribution is also met with in the case of *Dactylococcus bicaudatus*, *Chroococcus minutus*, *Nostoc sphaericum*, *N. paludosum*, *Oscillatoria formosa* and the smaller species of *Phormidium* like *P. angustissimum*, *P. tenue*, *P. molle*, but these seem to be less widely distributed.

Diverse genera that are represented in the soil-flora appear to be represented by different species in the temperate and tropical regions. Thus *Microcoleus* which is commonly represented by *M. vaginatus* in temperate regions [John, 1942 ; Petersen 1935], appears to be replaced by *M. ehthonoplastes* in India. The commonest species of *Nostoc* in the temperate countries is *N. commune* while in India *N. sphaericum* seems to predominate. The commonest soil diatom of temperate regions, *Hantzschia amphioxys*, is represented in the Indian soils studied, by the form *capitata* which appears not to have been recorded from temperate soils. *Navicula minuscula* which occurred commonly in many of the Allahabad soils has not been found in those of Europe.

On the other hand there are striking differences between the soil algal flora of the two regions, such as the absence of most *Xanthophyceae* to which attention has already been drawn. Common temperate soil algae like *Botrydiopsis*, *Heterothrix*, *Heterococcus* or *Bumilleria* appear to be lacking in the Indian soils and *Botrydium* is the only genus so far found. Many of the characteristic *Chlorophyceae* of temperate soils *viz. Stichococcus*, *Muriella* and *Zygogonium* appear to be absent from Indian soils. Among the *Myxophyceae* the only widespread temperate form that has not been recorded from Indian soils is *Plectonema Battersii*.

As regards the relative frequency of *Chlorophyceae* and *Myxophyceae* in the two regions, almost all European and American workers have noted the marked preponderance of the former over the latter. The ratios of numbers of *Chlorophyceae* to *Myxophyceae* observed in soil cultures of various workers in temperate countries are :—16 : 9 in Iceland [Petersen, 1928] 15 : 12 [Bristol, 1920], 13 : 1 [James, 1935], 45 : 21 [Fritsch and John, 1942] in European soils and 24 : 7 (Moore and Carter, 1926), 12 : 11 (Lowe and Moyse, 1934) in American soils. In the soils considered in this paper, however, a high proportion of *Myxophyceae* to *Chlorophyceae* was noted both with cultivated and uncultivated land. It seems impossible that the decided preponderance of *Myxophyceae* over *Chlorophyceae* observed in the present study was due to the alkalinity of the soils [cf. John, 1942] or to some being under cultivation. The dominance of the *Myxophyceae* is in accord with its important role in the subaerial and freshwater algal flora of the Tropics [Fritsch. 1907].

Summary

Sixteen samples of soils from North and South India have been examined for the presence of algae, by means of moist cultures and enrichment cultures prepared with various media and kept under different conditions. The soils examined can be classed broadly in three groups : (1) ordinary alluvial soils, (2) alkaline ' usar ' soils, and (3) red soils. The soils from rice-fields belonging to the first group represented a special environment and yielded a far larger number of species (70) than the other kinds of cultivated soils (number of species about 30). The ' usar ' soils have a high *p*H value and a greater percentage of carbonate coupled with a low content of total nitrogen and carbon than the other soils. The surface layers afforded only 23 species while the deeper layers showed the presence of only 5 species. The coarser mechanical composition of the red soils did not influence the occurrence of algae to any appreciable extent.

Myxophyceae comprise more than half the total number of species recorded in the soils, while the *Chlorophyceae* constitute only about one-third the total number. This is in marked contrast to the frequency of members of these classes in the soils of temperate countries where *Chlorophyceae* predominate. Other points of contrast between the algal flora of the two regions are afforded by the paucity of diatoms and *Xanthophyceae* in the Indian soils.

Chemical and mechanical analyses of the soils as well as a list of algae that appeared upon them are given.

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APPENDIX A

List of algae that appeared on the soils

Chlorophyceae

1. *Chlamydomonas Iyengari* Mitra
2. *C. indica* Mitra
3. *C. grandistigma* Mitra
4. *C. eugametos* Moewus var. *indica* Mitra
5. *C. gloeogama* Korschikoff
6. *Carteria intermedia* Mitra
7. *Carteria eugametos* Mitra
8. *Gonium pectorale* Mueller
9. *Coccomyxa subsphaerica* Chodat et Jaag var. *terrestre* Mitra
10. *Chloranomala palmelloides* Mitra
11. *Chlorococcum humicolum* (Nag.) Rabenhorst
12. *Chlorochytrium* sp.
13. *Chlorella vulgaris* Beijr.
14. *Chlorella botryoides* Petersen
15. *Tetraedron pentaedricum* W and G. S. West
16. *Dactylococcus bicaudatus* A. Br.
17. do. do. var. *curta* Mitra
18. *Dictyosphaerium pulchellum* Wood var. *minutum* Deflandre
19. *Scenedesmus obliquus* (Turp.) Kütz.
20. *S. prismaticus* Brühl and Biswas
21. *Uronema terrestre* Mitra
22. *Stigeoclonium* sp.
23. *Pleurastrum terrestre* Fr. and John var. *indica* Mitra
24. *Oedogonium pusillum* Kirchn. var. *catenatum* Mitra
25. *Spirogyra* sp. A and B.
26. *Protosiphon botryoides* Klebs forma *parieticola* Iyengar

Xanthophyceae

27. *Botrydium stoloniferum* Mitra

Chrysophyceae

28. *Ochromonas indica* Mitra

Bacillariophyceae

29. *Hantzschia amphioxys* (Ehr.) Grun. forma *capitata* Muller
30. *Navicula minuscula* Grun.
31. *Nitzschia* sp.

Myxophyceae

32. *Chroococcus minutus* (Kütz.) Nageli forma
33. *C. Westii* Petersen var. *terrestris* Mitra
34. *Synechococcus cedrorum* Sauvageau
35. *Aphanothece saxiola* Nageli
36. *Aphanothece bullosa* (Menegh.) Rabenhorst
37. *Gloeocapsa decorticans* (A. Br.) P. Richt.
38. *Chlorogloea Fritschii* Mitra
39. *Phormidium* ? *usterii* Schmidle
40. *Phormidium corium* Gomont forma *terrestre* Mitra
41. *P. rubroterricola* Gardner
42. *P. allahabadii* Mitra
43. *P. angustissimum* W. and G. S. West forma
44. *P. tenue* (Menegh) Gomont var. *indica* Mitra
45. *P. fragile* Gomont forma
46. *P. autumnale* (Ag.) Gomont
47. *P. uncinatum* Gomont
48. *P. foveolarum* (Mont.) Gomont
49. *P. molle* Gomont
50. *P. molle* Gom. forma *tenuior* G. S. West
51. *P. ambiguum* Gomont
52. *P. Hieronymusii* Lemm.
53. *P. Hieronymusii* Lemm. forma *major* Mitra
54. *Lyngbya aerugineo-coerulea* (Kütz) Gomont var. *terrestris* Mitra
55. *L. nigra* Ag. var. *gelatinosa* Mitra
56. *L. Iyengari* Mitra
57. *L. Iyengari* var. *violacea* Mitra
58. *L. rubida* Fremy
59. *L. rubida* F. forma.
60. *L. aestuarii* Liebm.
61. *L. Hieronymusii* Lemm.

62. *L. Hieronymusii* Lemm. var. *major* Mitra
63. *Oscillatoria princeps* Vaucher
64. *O. formosa* Bory forma
65. *Microcoleus chthonoplastes* Thuret.
66. *Crinalium magnum* Fritsch and John
67. *Anabaena ambigua* C. B. Rao
68. *A. allahabadii* Mitra
69. *Nostoc sphaericum* Vaucher
70. *N. Linckia* (Roth.) Bornet var. *globispora* Mitra
71. *N. paludosum* Kütz. forma
72. *N. paludosum* Kütz. var. *major* Mitra
73. *Calothrix catenata* Mitra
74. *C. membranacea* Schmidle
75. *C. membranacea* Schmidle var. *purpurea* Mitra
76. *C. anomala* Mitra
77. *Campylonema lahorense* Ghose var. *allahabadii* Mitra
78. *Scytonema Hofmanni* Ag.
79. *S. ocellatum* Bor. ? var. *purpureum* Gardner
80. *Fischerella mucicola* (Thuret) Gomont var. *indica* Mitra

STUDIES ON THE MECHANISM OF BIOSYNTHESIS OF NICOTINIC ACID DURING GERMINATION OF CEREALS AND PULSES

By H. N. De*, and S. C. Datta

Biochemistry and Nutrition Laboratories, Dacca University, Dacca, Pakistan.

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(With one text-figure)

THE importance of nicotinic acid in human and animal nutrition has been realised only in recent years, and for the required supply of this growth factor in their diets they have to depend mainly on the plant kingdom in which large scale synthesis of this and of other vitamins are taking place constantly. Cereals like wheat and rice and the different pulses as Bengal gram, *mung*, pea, *kalai*, etc. form the important constituents of our daily dietaries and these food materials contribute to our dietaries a major portion of the required nicotinic acid. But the mechanism of the process by which nicotinic acid and other members of B-complex are synthesised within the above plant products is not yet fully known.

In the laboratory, information in this line may be best gathered by the study of the change in the content of the above growth factor when these cereals and pulses are allowed to germinate under different conditions of the medium.

The present investigation has been taken up to study the mechanism of the biosynthesis of nicotinic acid in cereals and leguminous seeds during germination, i.e., to study the possible precursors and the different factors which influence the above biosynthetic process.

I. Effect of germination period on the biosynthesis of nicotinic acid in cereals and pulses

This Section aims to study the biosynthesis of nicotinic acid at different stages of germination. This also reports the effect of light and dark on the above biosynthetic process and the distribution of nicotinic acid in the cotyldons and embryos at different stages of germination.

Very few works are reported in the literature in this line and most of these are based on the studies on wheat, barley, maize and rice. Burkholder and his collaborators [1942 and 1943], Davis *et al.* [1943] and Klatzkin *et al.* [1948] found that although the oats and rice on germination showed increased values of nicotinic acid but the other two cereals as wheat and barley did not show any appreciable change in this respect.

Since no work has yet been done with the legumes as Bengal Gram, *mung*, pea, *kalai*, etc. these have, therefore, been selected for the study of the biosynthesis of nicotinic acid in the present investigation. The cereals as wheat and rice have also been used for comparative study.

* Assistant Professor of Biochemistry, M. G. M. Medical College, Indore, Madhya Bharat

When the present manuscript was being prepared the authors came acrosss the report by Banerjee and Banerjee [1950] who have also made similar attempts in the study of the biosynthesis of nicotinic acid by germinating pulses.

Experimental. The technique of germination was the same as adopted in the previous investigation from this laboratory by De and Barai [1949]. A number of batches of 4 to 5 gm. of seeds were first soaked in redistilled water for 4 to 6 hours and then allowed to germinate on ashless filter paper in petridishes covered with glass lids to prevent evaporation. The dishes were then placed on a table near a glass window facing north. For germination in the dark the petridishes were kept in a wooden box painted black both inside and outside and having a zigzag glass outlet for the circulation of the air. The seeds were kept moist by frequent additions of tridistilled water. Water, seeds and the petridishes were sterilised before the start of the experiments and the germination was carried out under asceptic conditions in both light and darkness for a consecutive period of seven days. After each 24 hours germination 3 to 4 batches of seeds were subjected to analysis for total nicotinic acid content after drying in an electric oven for 4 hours at 105°C. The dry weights gradually decreased with the progress of germination and the nicotinic acid values were expressed in terms of these dry weights.

Nicotinic acid content of the powdered dry seeds after germination was measured by the cyanogen-bromide method of Swaminathan [1942] with some modifications by Wang and Kodicek [1943] after hydrolysis with both acid, and with alkali with urea and the values indicate the free nicotinic acid, and also trigonelliene and other nicotinic acid derivatives if they are synthesised during germination, and all these are expressed as total nicotinic acid per gm. dry weight of the residual seeds after germination. In the present section and also in the succeeding ones the average values of 3 to 4 batches for each set of experiment have been presented in Table I.

Results and discussion

The results presented in Table I show that the nicotinic acid content of *mung* (*Phaseolus radiatus*), *kalai* (*Phaseolus mungo*), Bengal gram (*Cicer arietinum*), cowpea (*Vigna catiang*), pea (*Pisum sativum*), paddy (*Oryza sativa*) and wheat (*Triticum vulgare*) in the resting seeds are 22·7, 20·0, 25·6, 15·6, 13·8, 18·4 and 21·2 µgs respectively per gram dry weight. These values gradually increased as the germination proceeded and reached to the maximum level of 64·6, 46·5, 55·6, 33·0, 32·0, 30·2 and 33·2 µgs respectively at a certain period of germination which depended on the nature of the seed. These peak values manifest striking peculiarities when expressed as per cent increase over the initial non-germinated values. While calculating in this way (last column of the Table I) it is observed that the pulses in general produce higher per cent increase of nicotinic acid than the cereals. Of the five pulses studied, *mung* produced the maximum per cent increase of 186·2 whereas the cowpea the minimum of 111·6 p.c. It is further revealed that although Bengal gram possesses higher initial and peak values of 25·6 µg and 55·6 µg respectively whereas cowpea possesses comparatively lower initial and peak values of 15·6 µg and 33·0 µg respectively but they stand

TABLE I

Showing the effect of the period of germination on the biosynthesis of nicotinic acid in cereals and pulses. The values are expressed in μg per gram dry weight

Name of the seed	Germinated in	Period of germination in days							Per cent increase at the peak values*
		Zero	1st	2nd	3rd	4th	5th	6th	7th	
Mung (*Phaseolus radiatus*)	Light	22·7	28·4	33·5	44·0	64·6	52·3	43·3	34·8	186·2
	Dark	21·5	27·9	34·1	43·6	64·1	52·0	44·1	33·5	
Kalai (*Phaseolus mungo*)	Light	20·0	25·8	30·2	46·5	40·3	33·5	30·2	28·5	132·5
	Dark	19·2	26·4	31·0	45·8	41·0	33·1	31·5	28·9	
Bengal gram (*Cicer arietinum*)	Light	25·6	28·7	34·5	38·9	43·5	55·6	42·0	29·1	117·1
	Dark	26·2	28·0	33·6	39·2	43·2	54·8	42·5	28·5	
Cowpea (*Vigna catiang*)	Light	15·6	19·2	25·0	33·0	23·5	21·0	20·5	18·3	111·6
	Dark	16·0	19·8	25·2	32·1	23·0	21·8	20·1	19·0	
Pea (*Pisum sativum*)	Light	13·8	15·8	19·6	32·0	21·2	18·4	17·5	15·1	131·9
	Dark	14·5	15·2	20·1	32·7	20·9	18·6	17·0	15·9	
Paddy (*Oryza sativa*)	Light	18·4	19·5	30·2	22·1	21·4	20·0	18·6	16·2	64·1
	Dark	18·0	20·3	30·8	22·6	20·3	20·6	19·0	16·8	
Wheat (*Triticum vulgare*)	Light	21·2	22·5	33·2	30·0	28·3	25·1	23·2	20·0	58·1
	Dark	20·8	22·9	32·5	29·4	28·5	25·7	24·0	19·6	

* $\left[\frac{\text{Peak value}}{\text{Initial value}} - 1\right] \times 100$

in the same rank when the per cent increase of their peak values which ranged almost in the same limit of 117·1 and 111·6 per cent respectively for these pulses, are taken into consideration.

The present findings on wheat which showed sufficient increase in the nicotinic acid synthesis to the extent of 58·1 per cent is quite opposed to those of Klatzkin *et al.* [loc. cit.] who, however, could not find any significant increase in the nicotinic acid content when this cereal was germinated even for a longer period.

The results also show that the nicotinic acid values after peak level gradually decline with the further progress of germination (Fig. I). Similar decline after sharp rise in the nicotinic acid synthesis/in germinating wheat and corn is also noted in the results of Burkholder and McVeigh [loc. cit.] when these are carefully analysed. But this peculiar phenomenon in their results has passed over sight and so, has not been discussed in their report.

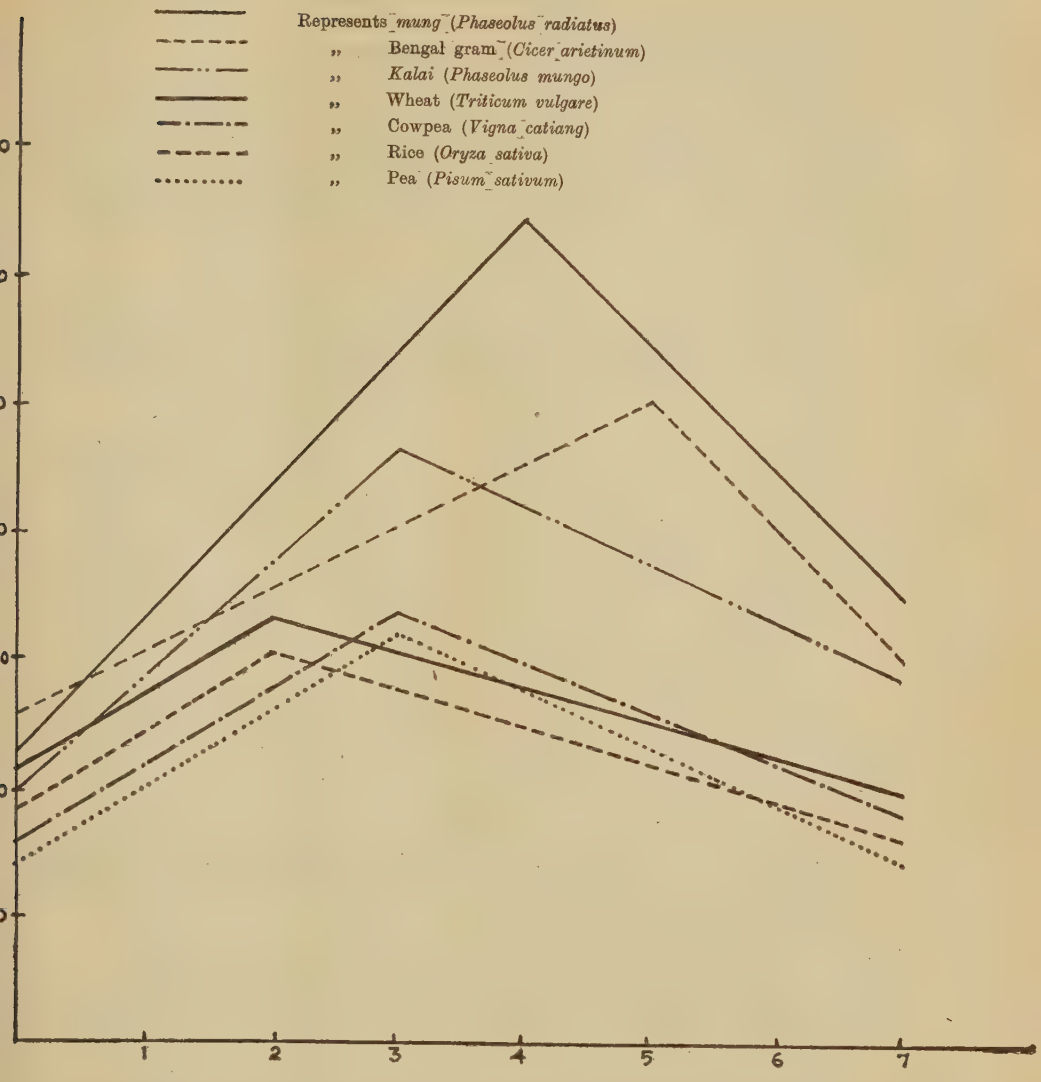
The above sudden depression after peak level is probably due to exhaustion of the precursors stored in the cotyldons. This stored precursors seem to be present in larger amount in the pulses specially in the *mung* and in lower amount in the cereals like wheat and rice as evident from the difference in the per cent increase of their peak values. Since the time at which the above peak values are reached are different for different pulses and cereals it may be interpreted that the exhaustion of the precursors stored in the cotyldons takes place at different periods of germination in different seeds.

Effect of light and chlorophyll. The results presented in the Table I also show the nicotinic acid values of the seeds whether germinated in diffused light or in darkness were almost the same and this indicates the independence of the nictonic acid synthesis on light. The results also indicate its independence on the chlorophyll content of plants as the white coloured dark germinated products showed equal amount of nicotinic acid as the green coloured light germinated ones. Terroine and Chabrel [1947] also observed similar independence on light in their experiments on hericot bean and *Phaseolus multiflorus*.

Distribution of nicotinic acid in embryos and cotyldons during germination

In this series of experiment the two pulses *mung* and pea were selected and they were germinated for a period of six days as before. The results presented in Table II show that the percentage distribution of nicotinic acid after 24 hours of germination were found to be 94·3 and 90·2 per cent for *mung* and pea cotyldons and 5·7 per cent and 9·8 per cent for their embryos. As the germination proceeded the percentage content of cotyldons decreased whereas those of embryos increased reciprocally and reached to the limit of 82·0 and 78·0 for *mung* and pea respectively at the 6th day of germination.

This observation is explained by the fact that at the initial stage of germination the nicotinic acid is synthesised in the cotyldons from the precursors stored therein. A portion of this is immediately transferred to the embryos which probably requires this growth factor during the early stages of development. After



1. Representing the sharp decline in the nicotinic acid content of different pulses and cereals following the peak values at certain stage of germination.

this the embryos attain the capacity to synthesise its own requirement of nicotinic acid and thus becomes autotrophic in this respect.

II. *Effect of nitrogenous fertilisers on the biosynthesis of nicotinic acid*

This Section aims to study the nitrogen precursors which might help the biosynthesis of nicotinic acid in germinating seeds. Since the synthesis of all the complex organic nitrogenous compound in the plant kingdom depends on the inorganic nitrogen sources of the soil it will be interesting to study whether the inorganic nitrogenous compounds as nitrates and ammonium salts, and also urea as employed as fertilisers when added in the germinating medium influence the biosynthesis of nicotinic acid in them.

TABLE II

Showing the distribution of nicotinic acid in cotyldons and embryos of legumes during germination. The values are expressed as percentage of the total content

Period of germination in hours	*Mung*		Pea	
	C*	E**	C*	E**
1×24	94·3	5·7	90·2	9·8
2×24	57·5	42·5	60·0	40·0
3×24	41·6	58·4	45·5	54·5
4×24	30·2	69·8	35·8	64·2
5×24	20·4	79·6	23·7	76·3
6×24	17·3	82·7	21·5	78·5

C* denotes cotyldons E** denotes embryos

TABLE III

Showing the effect of potassium nitrate, ammonium sulphate and urea on the nicotinic acid content of mung *and pea seeds and seedlings germinated in agar-agar medium composed of*:

Magnesium sulphate	0·2 gm.
Potassium chloride	0·2 gm.
Sodium sulphate	0·1 gm.
Calcium dihydrogen phosphate	0·1 gm.
Sucrose	10·0 gm.
Agar-agar	15·0 gm.
Redistilled water	1000 c.c.

TABLE III—*contd.*

Name of the seed	Name of the nitrogen supplement used	Intact seeds	Seedlings
		Nicotinic acid in μg per gm. dry wt.	Nicotinic acid in μg per gm. dry wt.
Mung	*nil*	43·0	67·5
	Potassium nitrate	61·4	86·5
	Ammonium sulphate	75·2	91·3
	Urea	40·6	70·2
Pea	*nil*	33·5	48·2
	Potassium nitrate	56·6	60·8
	Ammonium sulphate	68·2	67·4

It has been viewed by Schopfer [1943] that when the embryo is detached from the cotyldon it becomes auxohetotrophic as far as the vitamins are concerned because of its dependence on the cotyldons for the supply of these growth factors. It will also be interesting to study whether the embryos detached from the cotyldons can perform the active process of synthesis of nicotinic acid when incubated with the above nitrogenous compounds.

Experimental. Mung and pea were selected as the typical legumes for this experiment and both the intact seeds and the embryos, detached from the cotyldons, were subjected to germination.

The intact seeds were germinated in agar-agar medium (40 c.c.) the composition of which is shown in Table III, in which different nitrogenous compounds as potassium nitrate, ammonium sulphate and urea were added separately in doses of 10 mg., 6·5 mg. and 3·5 mg. respectively, for each 40 c.c. medium. The concentration difference of the three compounds as shown above were mainly to keep the level of the elementary nitrogen constant.

For germination of the seedlings the seeds were first allowed to germinate on moist filter paper placed in petridishes for three days.

After this period the embryos were separated from the cotyldons and allowed to germinate for further period of three days in the agar-agar medium with the supplementation of the above nitrogenous compounds in the same way as above.

Experiments were carried out both in light and darkness strictly under sterile conditions. Since the values for both light and dark germination were almost the same, only those of the light germination have therefore been presented in the table.

Results and discussion

The results presented in Table III show that both potassium nitrate and ammonium sulphate can stimulate the biosynthesis of nicotinic acid both in intact seeds and in the embroys when they are germinated with the above salts in the medium.

The results of embryo experiment further show that embryos possess the capacity to synthesise nicotinic acid even from the exogenous inorganic nitrogenous precursors, i.e. the embryos are autotrophic with regard to vitamins even when they are detached from precursors present in cotyldons provided the nitrogenous precursors as potassium nitrate, ammonium salts or any other salts are supplied externally.

It is further revealed that the enzyme system involved in the above synthesis of nicotinic acid is probably located in the embryos and originate as soon as the seeds are germinated. With the help of these enzyme systems the embryos synthesise nicotinic acid from the precursors stored in the cotyldons and the process proceeds unhampered until the precursors are exhausted.

It is also not improbable that the nicotinic acid after synthesis enters into some enzyme systems as the prosthetic group for the performance of the vital processes necessary for the growth of the embryos and the plant as a whole. When the stored nitrogenous precursors are exhausted the synthesis is however checked but its requirement for the above vital processes remains still unaltered and so the nicotinic acid which had previously been synthesised is gradually exhausted. This explains the reason for the sharp decline after the peak value of nicotinic acid synthesis during germination as described in the previous section.

In case of both the intact seeds and seedlings the effect of ammonium salt was found to be more prominent than that of nitrates.

The superiority of ammonium sulphate is explained by the fact that the synthesis of protein and other complex nitrogenous compounds in plants is preceded by the synthesis of amide and amino acids, for which the absorption of nitrogen in the form of ammonia is primarily necessary and even when nitrate is added it must pass through nitrite and ammonia before absorption as viewed by Chibnall [1939] and Vickery *et. al.* [1938 and 1939] and others.

The results of the table also show that urea is ineffective in the above biosynthetic process and this is probably due to failure of the above seeds to convert urea to ammonium salts.

III. Effect of arginine, proline and tryptophane on biosynthesis on nicotinic acid

Under this heading is reported the possible intermediates involved in synthesis of nicotinic acid from the inorganic nitrogenous compounds as discussed in the previous section.

Guggenheim [1940] has suggested a scheme based on ornithine and proline as the starting materials and with d-amino valeric acid, guvacine as the intermediates. By feeding experiments on rats and by *in vitro* tissue culture experiments with their liver and kidney tissues it has been reported by De and Datta [1951] and De and

Guha [1951] that the above scheme does not successfully operate when applied to animals. In the present investigation some of the intermediates as suggested by Guggenheim [1940] have been tested to see whether this scheme is valid in case of plant kingdom.

It has been reported by different workers that tryptophane can replace nicotinic acid for the preventation of pellagra and that it is easily converted to nicotinic acid in the animal body [Krehl *et al.*, 1946 ; Singla *et al.*, 1946 ; Sarett *et al.*, 1947 ; Perlzweig *et. al.*, 1947 and others]. Recent investigation from this laboratory by De and his coworkers [*loc. cit.*] has shown that this conversion takes place not only in the intestine by the microflora inhabiting there but also in the tissues like liver, kidney, etc. The present investigation has, therefore, been undertaken to see whether tryptophane can also stimulate the biosynthesis of nicotinic acid in the seeds when they are germinated with it.

Experimental. Mung seeds were germinated in sterilised agar-agar medium with different doses of l-arginine, d-arginine, l-proline and l-tryptophane separately. Control experiment without any amino acid dose was arranged to compare the effect of the above supplements. Germination was conducted for three days and only in diffused light.

Results and discussion

The results presented in Table IV show that l-arginine stimulates the biosynthesis of nicotinic acid during germination of *mung* seed at all doses of supplement from 10 to 1000 p.p.m. whereas the d-isomer failed to do so.

Table IV

Showing the effect of different amino acids on the biosynthesis of nicotinic acid in germinating mung *seed. Period of germination—three days*

Name of the amino acid	Dose of the amino acid in p.p.m.	Nicotinic acid in μg per gm. dry weight
l-arginine.	0	45·5
	10	*62·3*
	100	59·1
	1000	57·3
d-arginine.	0	46·7
	10	45·2
	100	47·4
	1000	44·8
l-proline.	0	43·5
	10	46·8
	100	46·7
	1000	47·2
l-tryptophane.	0	45·9
	10	49·6
	100	56·3
	1000	*69·1*

This difference in the ability of the two optically active isomers of arginine to stimulate the biosynthesis of nicotinic acid apparently seems to be much striking but may easily be explained on the basis of the fact that almost all the plant seeds contain the enzyme arginase which only acts on the l-isomer breaking it to urea and ornithine. Since ornithine could not be procured, experiment with this could not be performed.

The results also show that l-proline cannot stimulate the biosynthesis of nicotinic acid even added at higher dose of 1000 p.p.m.

Guggenheim has postulated two possible pathways for the conversion of ornithine to d-amino valeric acid in his biosynthetic mechanism one (a) by direct conversion of ornithine to d-amino valeric acid by simultaneous deamination and reduction without passing through proline and another (b) through the intermediary of proline. But since proline cannot stimulate the above biosynthetic process as observed in this investigation it may be postulated that in the conversion of ornithine or its precursor arginine to nicotinic acid proline does not constitute the intermediate, *i.e.*, the process follows the first pathway as suggested by Guggenheim.

The present results also show that l-tryptophane can help in the biosynthesis of nicotinic acid when added in the culture medium of the germinating *mung* seeds in a manner similar in case of rats and other animals. The results are at variance with that obtained by Terroine [1948] who did not find any increased synthesis of nicotinic acid in the germ of *Phaseolus multiflours* after addition of tryptophane in the medium.

But whether tryptophane constitutes actually the stored precursor in the cotyldon for nicotinic acid synthesis will be made clear from the experiments detailed in the next section.

IV. *Effect of different B-vitamins on the biosynthesis of nicotinic acid*

Recent investigations have revealed that almost all the members of B-vitamins constitute the important components of the coenzymes of different enzyme systems as dehydrogenases, carboxylase, decarboxylase, amino acid oxidase, deaminase, etc. which are widely distributed in the animal and also in the plant kingdom. Since in the synthesis of all complex organic compounds in the plant body some enzyme systems are involved, it is not improbable that in the biosynthesis of nicotinic acid also, one or more of the above and other enzymes take active part ; and with this possibility in view the following experiment has been carried out to see how far the addition of different members of B-vitamins in the medium of germinating seeds influence the biosynthesis of nicotinic acid during germination.

In case of animals and microorganisms sufficient evidences have accumulated to show that the synthesis of one vitamin is stimulated by the presence of the others in the diet or in the culture medium but in case of plant only a few works are reported to have been undertaken in this line. Bonner [1938] found that the embryo of perfection variety of pea cultivated in a solution containing thiamine as the only growth factor exhibited a marked increase in growth and in ascorbic acid content and thus indicated the stimulation of ascorbic acid synthesis by thiamine.

The present work will supply an additional information regarding the effect of one member of B-vitamins on the biosynthesis of the other.

Experimental. The experimental procedure was the same as in section III above. Thiamine, riboflavin, pantothenic acid and pyridoxine were added in the culture medium in doses of 10, 100 and 1000 μg. per 40 c.c. of the medium. All experiments were performed in light.

TABLE V

The effect of some B-vitamins on the biosynthesis of nicotinic acid in germinating mung *seed. Period of germination—three days*

Name of the amino acid supplement	Dose of the amino acid in p.p.m.	Nicotinic acid in μg per gm. dry weight
Thiamine	0	37·1
	10	49·6
	100	*70·6*
	1000	45·3
Riboflavin	0	41·3
	10	*67·5*
	100	61·4
	1000	38·5
Pantothenic acid	0	39·2
	10	45·5
	100	*53·1*
	1000	43·7
Pyridoxine	0	42·1
	10	38·2
	100	41·5
	1000	44·7

RESULTS AND DISCUSSION

It is observed from the results of Table V that of the four vitamins studied thiamine effected the maximum biosynthesis of nicotinic acid, pantothenic acid the least, and riboflavin stands in between these two extremes. Pyridoxine did not influence the biosynthesis at any dose of supplementation. The maximum nicotinic acid content of germinated *mung* seeds due to dosing with thiamine, riboflavin and

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pantothenic acid were found to be 70·6 μg, 67·6 μg and 53·1 μg as against the controls 37·1 μg, 41·3 μg and 39·2 μg respectively per gm. dry weight.

It is further noted from the table that the concentration of the doses of the vitamins at which the nicotinic acid synthesis shows its maximum value varies with respect to different members. Thus with riboflavin the maximum stimulation was observed at the dose of 10 μg whereas in case of thiamine and pantothenic acid the optimum doses were found in the region of 100 μg.

Since thiamine, riboflavin, and pantothenic acid aid in the biosynthetic process it may be conceived that the processes of carboxylation, dehydrogenation and acetylation are directly or indirectly involved in the above synthesis of nicotinic acid in the germinating seeds.

To explain as to how the synthesis of nicotinic acid occurs at ordinary stage of germination in redistilled water without any added dose of the above growth factor it may be stressed that in the resting seeds at the ordinary state some amount of thiamine, riboflavin and pantothenic are already stored in the cotyledons and more of these are probably synthesised when the seeds are germinated. These then, by entering into complex with the different proteins, constitute some enzyme systems which thereby aid in the synthesis of nicotinic acid.

The mechanism by which the addition of either of the above three growth factors in the medium increase the nicotinic acid content of the germinating seed is explained in the following way : It will not be unreasonable to conceive that the synthesis of different vitamins in the plant kingdom take place symbiotically *i.e.*, the synthesis of one helps in the synthesis of the other. So nicotinic acid already stored and synthesised during germination, in turn, seem to aid in the synthesis of thiamine, riboflavin, pantothenic acid and other growth factors. Thus a certain amount of synthesised nicotinic acid is always utilised for the above purpose and get destroyed. But if thiamine riboflavin, pantothenic, etc., are supplied from outside for the performance of the vital processes for the growth of the plant, naturally a large amount of nicotinic acid will be spared and so will remain stored in the germinated seeds.

The ineffectiveness of pyridoxine in the nicotinic acid synthesis in the germinating pulse as observed in this investigation seems to be very striking and helps in the real understanding of the possible intermediate in the above biosynthetic process. By studying with rats and *Neurospaora* it has been shown by Grace *et al.* [1948], Juenqueria *et al.* [1948], Ling and Hegsted [1948], Mitchell *et al.* [1948], Bonner *et. al.* [1949 and 1950] and others that pyridoxine aids in the biosynthesis of nicotinic acid and its action is elaborated by its influence in converting kynurenine to hydroxyanthranilic acid the two possible intermediates in the pathway of the conversion of tryptophane to nicotinic acid. The failure of this growth factor to stimulate the biosynthesis of nicotinic acid in the germinating seeds, therefore, suggests that in the germinating seeds tryptophane does not constitute the actual precursor or the intermediate in the above synthetic process although this can only help when added from outside. This view is further substantiated by the observations presented in Table VI in which it has been shown that pyridoxine although

cannot stimulate the nicotinic acid when added alone in the medium but can do so when added in combination with tryptophane.

TABLE VI

Effect of pyridoxine on the biosynthesis of nicotinic acid in mung *seeds and seedlings germinated with tryptophane. Period of germination—three days*

	Conc., of tryptophane in p.p.m.	Conc. of pyridoxine in p.p.m.	Nicotinic acid in μg per gm. dry wt.
Mung seeds	1000	*nil*	63·7
	1000	1000	79·5
Mung seedlings	1000	*nil*	86·4
	1000	1000	121·7

These observations may otherwise be explained by that although free tryptophane has been found to be present in the germinating seeds by some workers but the concentration does not seem to be sufficient which may be utilised for purposes other than for portein synthesis. Similar view has also been expressed by Skogg [1947] while discussing the controversy regarding the possibility of tryptophane as the auxin precursor in the plant body.

V. Effect of trace elements on the biosynthesis of nicotinic acid

The importance of trace elements like iron, copper, manganese, zinc, nickel and others for the nutrition of animals, plants and micro-organisms has been realised only in recent years and evidences are gradually accumulating in the literature to show that their role is exerted through some enzyme systems in the prosthetic groups of which, these elements constitute the important components and whose activity depends in some cases on the property of these elements to undergo reversible oxidation and reduction. Since in the biosynthesis of nicotinic acid during germination of legumes a large aggregate of different enzymes systems are involved it will be worthwhile to study whether the different trace elements which constitute the prosthetic groups of some enzymes might influence the above biosynthetic process, and with this in view the present experiment has been arranged.

Very few works have been done in this line of plant nutrition. Utiger and Schopfer [1941] have demonstrated the great importance of mineral catalysers present as impurities in the organic constituents of the medium, in the synthesis of vitamin in *Rhodotovula rubra* and *Mucor ramannianus*. Schopfer in 1943 also found that copper, iron, manganese, molybdenum and zinc if added separately favours the production of biotin by *Phycomyces blackesleanus*.

Experimental. Experimental procedure was the same as in section III. Solution of manganese chloride, copper (ic) chloride, iron (ic) chloride, zinc chloride and

nickel chloride were added in the agar-agar culture medium in doses of 10, 100 and 1000 p.p.m. per 40 c.c. medium used.

TABLE VII

Showing the effect of microelements on the biosynthesis of nicotinic acid in germinating mung *seeds. Period of germination—three days*

Name of the salt supplement used	Dose of the salt solution in p.p.m.	Nicotinic acid in μg per gm. dry weight
Manganese chloride	0	36·2
	10	*60·5*
	100	45·7
	1000	39·4
Cupric chloride	0	35·1
	10	*53·3*
	100	41·2
	1000	24·7
Ferric chloride	0	38·4
	10	*50·7*
	100	38·1
	1000	22·6
Zinc chloride	0	34·2
	10	43·8
	100	58·7
	1000	38·2
Nickel chloride	0	38·1
	10	35·9
	100	35·8
	1000	32·5

RESULTS AND DISCUSSIONS

The results of the experiment presented in Table VII show that except nickel all the other elements as iron, copper, manganese and zinc augmented the biosynthesis

of nicotinic acid in the germinating *mung* seed. It is further observed that in all these cases the synthesis was augmented up to a certain dose of the salt solution above which the synthesis was retarded and in some cases depressed. Of the four elements manganese produced the maximum effect, then stands zinc, copper and iron in this respect—the maximum values with these were found to be 60·5 μg, 58·7 μg, 50·1 μg and 47·4 per gram dry weight respectively. The salt concentration at which these maximum values are produced are different for the above four elements. In case of iron, copper and manganese the optimum salt concentration was at 10 p.p.m. whereas in case of zinc the optimum concentration was at 100 p.p.m.

The stimulation of biosynthesis by iron, copper and manganese takes place most probably by the transfer of hydrogen or oxygen by some enzymes in which these elements constitute the prosthetic groups. The stimulatory effect of zinc seems to be related to some enzymes other than oxidation-reduction system. The observations by Bean [1942] that the deficiency of zinc in the soil produced retardation in the protein synthesis and of the oxidase and catalase activities suggest that the above stimulation of nicotinic acid by this element might be indirectly elaborated by its influence on the above protein synthesis and oxidase and catalase activities.

The inhibition of the biosynthesis due to high dose of the above elements as observed in the present investigation may be explained as either (a) due to competition of one with the other, when the former is added in excess, for the occupation of the active site in the organo-metallic protein complex which probably constitutes some enzyme systems in the above process, or (b) due to blocking of the active —SH group of the protein moiety of some oxidase or peroxidases as might be present in the germinated seeds and be involved in the above synthetic process. Which of these two possibilities are more plausible will be made evident from the experiment detailed in the next section.

VI. Investigation on the enzymes involved in nicotinic acid synthesis is germinating seeds

The present section aims to study the possibility of the presence of —SH group in the nicotinic-acid-synthesising enzyme systems postulated in the previous section.

It has been shown by different workers as Hellerman *et al.* [1941] and [1943], Hellerman [1937], Dixon [1940], Barron *et al.* [1945] and others that some hydrolytic and oxidative enzymes owe their activities to the presence of active —SH group in the protein moiety of the enzymes. The presence of this group has been detected by observing the inactivation of the enzymes by different oxidising agents, alkalyting agents and mercaptide forming compounds and also by observing their reactivation after addition of glutathione (GSH) and cysteine. In the present investigation the mercaptide forming compound as potassium arsenite has been used as the inactivating agent and glutathione and cysteine as the reactivating agents to detect the possibility of the presence of —SH group in the enzyme systems under investigation.

Experimental

The following four batches of experiments were performed.

Batch No. 1.—Intact *mung* seeds germinated in ordinary agar-agar medium with graded doses of potassium arsenite and seedlings germinated in the same medium with ammonium sulphate and graded doses of potassium arsenite.

Batch No. 2.—*Mung* seedlings germinated in agar-agar medium with ammonium sulphate and supplemented with potassium arsenite, potassium arsenite+ glutathione, and potassium arsenite + cysteine.

Batch No. 3.—*Mung* seedlings germinated in agar-agar medium with ammonium sulphate alone and along with graded dose of glutathione.

Batch No. 4.—*Mung* seedlings germinated in agar-agar medium with ammonium sulphate supplemented with copper chloride, manganese chloride, copper chloride+ glutathione, and manganese chloride+ glutathione.

Technique of germination was the same as in the previous sections.

Table VIII

Effect of different doses of potassium arsenite on the biosynthesis of nicotinic acid in germinated seeds and seedlings. Period of germination—three days

Doses of potassium arsenite in p.p.m.	Nicotinic acid in μg per gm. dry wt.	
	Seeds*	Seedlings**
0	33·9	64·3
10	46·1	88·7
100	52·5	83·2
1000	42·1	48·8

*4 gm. seeds were germinated in ordinary agar-agar medium.
**80 Seedlings were germinated in agar-agar medium supplemented wilh 6·5 gm. ammonium sulphate.

Results and discussion

Experiment 1

The results presented in Table VIII show that the addition of potassium arsenite in the medium of *mung* seeds germinated in ordinary agar-agar medium and of seedlings germinated in ammonium sulphate solution increased their nicotinic acid content—the increment was found to be more prominent in seedlings than in intact seeds.

Since this agent blocks the —SH group the above increase in the nicotinic acid content due to this agent may be explained as due to the presence of the active —SH group in those enzyme systems which are involved in the utilisation of

nicotinic acid for some metabolic functions necessary for the growth of the plant. The inactivation of such nicotinic-acid-utilising enzymes by the above agent spares a large amount of nicotinic acid for storage in the seedlings and in the seeds as a whole.

TABLE IX

Effect of potassium arsenite alone and in combination with glutathione or cysteine on the biosynthesis of mung *sedlings. 80 seedlings were germinated for three days in agar-agar medium with 6·5 ammonium sulphate*

Reagents used	Nicotinic acid content in μg per gm. dry weight
Nil	69·1
Potassium arsenite (100 p.p.m.)	88·5
Potassium arsenite (100 p.p.m.)+glutathione (100 p.p.m.)	70·3
Potassium arsenite (100 p.p.m.) + cysteine (100 p.p.m.)	58·8

Experiment 2

The above concept is substantiated by the observations presented in Table IX from which it is found that the nicotinic acid content of seedlings due to dosing with arsenite + glutathione and arsenite+ cysteine is less than due to dosing with arsenite alone thus showing that when cysteine or glutathione are present in the medium along with arsenite from the beginning of germination their active—SH group, because of its greater affinity than the similar group of the nicotinic-acid-utilising enzyme systems for interaction with arsenite, is attacked by this agent more easily leaving the nicotinic-acid-utilising enzyme systems unaffected. When arsenite is present alone in the medium it will readily attack the nicotinic-acid-utilising enzyme systems having the active—SH group and so comparatively lower storage of nicotinic acid than the previous case of double supplements with cysteine or glutathione will be obtained in the present one.

TABLE X

Showing the effect of graded doses of glutathione (GSH) on the biosynthesis of mung *seedlings germinated in agar-agar medium with 6·5 gm. ammonium sulphate. Period of germination—three days and seedlings taken 80*

Doses of glutathione in p.p.m.	Nicotinic acid in μg per gm. dry wt.
0	68·1
10	70·3
100	66·4
1000	53·7

Experiment 3

More conclusive evidences in aid of this concept are available from the results of Table X in which it has been shown that glutathione added in the medium in doses upto 100 p.p.m. do not affect the nicotinic acid content of the seedlings, and this indicates that the active—SH group is not probably present in those enzymes which are involved in the biosynthesis of nicotinic acid. It is further observed from the table that at high dose of glutathione supplement the nicotinic acid content is diminished and this seems to be due to increase in the concentration of the—SH group containing nicotinic-acid-utilising enzyme systems as a result of the donation of the—SH group by the excess glutathione.

Experiment 4

Since the nicotinic-acid-synthesising enzyme systems do not seem to contain the active—SH group as evident from the above experiments it may be conceived that the inhibition of the nicotinic acid synthesis due to high dose of iron, copper manganese and zinc salts as observed in the previous section is not due to their interaction with the —SH group but probably due to their mutual competition for the occupation of an active site in the metallic-protein-complex enzyme systems which seem to be involved in the biosynthesis of nicotinic acid as postulate in the previous section.

Evidences in aid of this concept are obtained from the results of Table XI from which it is observed that the *mung* seedling when grown alone in high dose of manganese or copper chloride show decreased values of nicotinic acid but higher values when they are grown in the above salts along with glutathione.

TABLE XI

Showing the effect of high dose of copper and manganese chlorides alone and in combination of glutathione on the nicotinic acid synthesis in mung *seedlings grown in agar-agar medium supplemented with 6·5 gm. ammonium sulphate. Eighty seedlings germinated for three days*

Reagent added in the agar-agar medium	Nicotinic acid in μg per gm. dry weight
Nil	68·3
Manganese chloride 100 p.p.m.	46·2
Copper chloride 100 p.p.m.	41·7
Manganese chloride 100 p.p.m.+glutathione 100 p.p.m.	55·9
Copper chloride 100 p.p.m.+glutathione 100 p.p.m.	59·5

This increased value due to combined dosing of glutathione and the above metallic salts is probably due to interaction or combination of the—SH group of

glutathione with the excess copper and manganese ions which would otherwise have blocked the nicotinic-acid-synthesising enzyme systems by mutual antagonism and would have thus decreased the total nicotinic acid content.

Summary

Synthesis of nicotinic acid occurs in the pulses as *mung*, *kalai*, Bengal gram, pea, and cowpea and in cereals as wheat and paddy when these are subjected to germination. The above biosynthesis reaches to a maximum level at certain period of germination beyond which it declines. The germination period of the optimum value depends on the nature of the seed.

Light and chlorophyll do not seem to influence the above biosynthetic process.

At the initial stage of germination the percentage distribution of nicotinic acid was greater in cotyldons and less in the embryos but at the later stage the above distribution was reversed.

Both ammonium sulphate and potassium nitrate when added in the medium accelerated the nicotinic acid synthesis in the germinated *mung* seeds and seedlings—the effect was found to be more prominent in case of ammonium sulphate. Urea failed to stimulate the above process.

Study of the effect of amino acids have shown that l-arginine and l-tryptophane stimulated the biosynthesis of nicotinic acid in the germinated seedlings when added in their medium whereas l-proline and d-arginine were ineffective in this respect.

The addition of thiamine, riboflavin and pantothenic acid in the medium of germinating *mung* seeds accelerated the above biosynthetic process. The failure of pyridoxine to stimulate this process suggested that tryptophane is not the actual precursor for nicotinic acid synthesis in the germinating seeds.

Up to a certain concentration, the addition of the iron, copper, manganese and zinc salts in the germinating medium augmented the biosynthesis of nicotinic acid. At their high dose the synthesis was inhibited. Nickel did not produce any effect at any dose.

By employing potassium arsenite, glutathione and cysteine it has been revealed that an active —SH group is present in the enzyme systems which are involved in the utilisation of nicotinic acid for the performance of some vital metabolic functions necessary for the growth of the seedlings and the plant as a whole.

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EFFECT OF COLCHICINE ON THE SYNTHESIS OF NICOTINIC ACID IN GERMINATING SEEDS

By H. N. De and S. C. Datta, Biochemistry and Nutrition Laboratories, Dacca University, Dacca, Pakistan

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THE observations by different workers that autopolyploid varieties of crops are commercially more valuable than the diploids led some investigators to devise some technique for the artificial production of polyploid varieties of crops by treating the seeds with some chemicals and also by heat and X-ray exposures. Of the different chemicals studied the alkaloid-colchicine has been found to be most effective in this respect [Blackslee and Avery, 1937 ; Derman, 1940] but the mechanism of the process by which the above effect is produced is not yet definitely known. It is not unreasonable to conceive that the normal functions of the different phases of mitosis and meosis are the manifestations of a chain of enzyme reactions and that the induction of polyploidy by colchicine or other treatments is possibly the result of derangement in the above functions of enzyme systems as influenced by colchicine or other chemicals, or their split products. In some enzyme systems of both plant and animal kingdom, specially in those which are concerned in the process of dehydrogenation, carboxylation, decarboxylation, deamination, acetylation, etc. some of the important members of B-vitamins constitute the prosthetic groups and it is so expected that the induction of polyploidy by colchicine treatment might bring about some changes in the concentration of the above vitamins resulting with simultaneous inhabition or acceleration of the above or other enzyme systems, and with this possibility in view a series of investigations have been started in this laboratory. The present report deals with the study of the effect of colchicine treatment on the synthesis of nicotinic acid in germinating seeds and represent the first of the above series.

The recent investigations from this laboratory by De and Datta [1951] and De and Elahi [1951] that a large amount of nicotinic acid is synthesised during germination of pulses and cereals and that the enzymes involved in the above process of synthesis, as isolated from the embroyes of the above germinating seeds, can synthesis nicotinic acid not only from the amino acid precursors like arginine or tryptophane but also from the simple inorganic nitrogenous source —ammonium sulphate have also prompted us to study the effect of colchicine on the above process of synthesis.

Some works are reported in the literature regarding the change in the chemical constituents of the plyploid plants produced artificially by colchicine and other treatments, in relation to the original diploid and in some cases as the alkaloid content [Kostoff and Nikoloff, 1941; Miller and Fischer, 1946], ascorbic acid content [Melville and Pyke, 1941], carotene content [Randolph and Hand, 1940], nitrogen content [Kostoff and Nikloff, loc cit ; Elis *et al*, 1945] and catalase and maltase activities

[Chen and Tang, 1945 loc cit ; Elis *et el*, 1945] great increase of these values have been noted in tetraploid or polyploid plants whereas in case of some other constituents as total pigment content [Leven, 1943], cellulose content [Kostoff and Nikoloff, loc cit], sugar content [Abegg, 1942] and M. B. reduction rate of some alcohols and amino acids [Chen and Tang, loc cit] reduced values have been obtained in the tetraploid plants. But since in all the above cases the estimation of the constituents have been made on the subsequent crops or leaves after polyploidisation has been induced in them, the above findings do not present any clear idea as to how and to what extent the above changes in the chemical constituents have undergone just when polyploidisation is induced during the treatment with the above chemicals. Information in this line is best gathered only by measuring the different chemical constituents, vitamins and enzyme activities of the seeds when their original diploid varieties are germinated with and without colchicine or other polyploidising agents and it is why in the present investigation the effect of colchicine-induced polyploidy on the nicotinic acid synthesis in plants has been studied when the seeds undergo germination with the above agent.

Experimental

Mung (*Phaseolus radiatus*, 2n=24) and pea (*Pisum sativum*, 2n=14) being the two typical pulses having the maximum and minimum nicotinic acid content [De and Datta, loc cit] were selected for studies in the present investigation. A large batches of the seeds of these two pulses—each batch containing four to five gm. of seeds—were divided into two sets. One set, after soaking for four to six hours in tri-distilled water was germinated in the usual manner in the ashless filter paper in the petri-dishes covered with glass lids to prevent evaporation. The seeds were kept moist by frequent additions of tri-distilled water and germination was continued for a consecutive period of five days. This set constitutes the control experiment. Another set was also germinated in the same way in the tri-distilled water but the seeds before germination were treated with 0·1 per cent colchicine solution for 24 hours to induce polyploidy according to the technique described by Derman [loc cit]. After each 24 hours germination three to four batches of seeds from each of the above two sets of experiments were separated from the rest and their nicotinic acid content was measured after drying the germinated seeds in an electric oven at 105°C. for 4 hours.

Another series of experiment was also arranged in which the control and the colchicine-treated seeds were germinated in the agar-agar medium containing 6·5 gm. of ammonium sulphate per 40 c.c. of the medium as the external source of nitrogen precursor for nicotinic acid synthesis. The germination was continued for three consecutive days and after this the seeds of both control and colchicine-treated sets were dried as before and analyzed for their nicotinic acid contents. Tri-distilled water, agar-agar medium and the petri-dishes were previously sterilised and the germination of all the experiments was carried out in light in an incubator at 30°C. The technique of germination and other details of experiment were the same as reported in the previous investigations from this laboratory by De and Barai [1949] and De and Datta [loc cit].

Nicotinic acid content of the powdered dry seeds was measured by the cyanogen-bromide method of Swaminathan [1942] with some modifications according to the method of Wang and Kodicek [1943] after hydrolysis both with acid and with alkali with urea and the values indicate the free nicotinic acid, and also trigonelline and other nicotinic acid derivatives if they are at all synthesised during germination and all these values have been expressed as total nicotinic acid per gram dry weight of the seeds.

Trace of colchicine which might be present in the seed extract as contamination did not influence the above colour reactions of nicotinic acid estimations as was evident from the blank experiment performed by using colchicine along with cyanogen-bromide and other reagents.

TABLE I

Effect of colchicine treatment on the biosynthesis of nicotinic acid in mung *and pea seeds at different stages of germination. The values represent the averages of 3 to 4 batches of seeds germinated in tri-distilled water*

Name of the legume	Period of germination in hours	Nicotinic acid content expressed in μg, per gram dry weight	
		Colchicine-treated seeds	Untreated seeds
Mung (*Phaseolus radiatus*, 2n=24)	24×1	18·2	28·8
	24×2	28·5	32·6
	24×3	*40·3*	*51·0*
	24×4	24·0	31·5
	24×5	17·2	23·1
	Value of original ungerminated seed—22·1		
Pea (*Pisum sativum*, 2n=14)	24×1	12·0	15·2
	24×2	13·8	18·8
	24×3	20·0	29·8
	24×4	*23·5*	*36·3*
	24×5	20·2	26·5
	Value of original ungerminated seed—14·5		

Results and discussion

Cytological studies

The colchicine-treated seeds manifested typical characteristics of polyploidy. The seeds were sturdier in appearance and the seedlings thick and short due to slower rate of growth. The cytological studies* revealed that both the *mung* and pea seeds became octaploid by colchicine treatment.

Studies on nicotinic acid content

The results presented in Table I show that the colchicine-treated seeds of both *mung* and pea pulses contain less amount of nicotinic acid than the untreated ones at all periods of germination when carried on only in distilled water. In our previous studies [De and Datta, 1951] it has been noted that the nicotinic acid content reaches to a peak value at a certain period of germination after which it declines. Similar phenomena has also been observed in the present investigation but the peak values attained by the colchicine-treated seeds were significantly lower than the untreated ones.

Table II

Effect of colchicine treatment on the biosynthesis of nicotinic acid in mung *and pea seed germinated in agar-agar medium† supplemented with 6·5 gm. ammonium sulphate per 40 c.c. medium used for each batch of germinating seeds. The values represent the averages for three batches of seeds after germination for three days*

Name of the legume	Nicotinic acid content in μg per gm. dry weight	
	Colchicine-treated seeds	Untreated seeds
Mung (*Phaseolus radiatus*)	50·9	77·8
Pea (*Pisum sativum*)	25·1	44·6

† *Composition of agar-agar medium :—Magnesium sulphate 0·2 gm. ; potassium chloride 0·2 gm., sodium sulphate 0·1 gm., calcium dihydrogen phosphate 0·1 gm., sucrose 10·0 gm., agar-agar 16·0 gm. and tri-distilled water 1000 c.c.*

The above difference in the nicotinic acid content between the colchicine-treated and—untreated seeds is more prominently evinced from the experiment of the second series (Table II) in which the seeds were germinated in the agar-agar medium with ammonium sulphate as the external source of nitrogen for nicotinic acid synthesis and the values for colchicine-treated and -untreated seeds were found to be 50·9 μg and 77·8 μg respectively in case of *mung* seed and 25·1 μg and 44·6 μg in case of pea seed.

The above lower value of colchicine-treated seeds as evident from the data of Tables I and II may be either due to lower synthesis of this vitamin under the influence of this alkaloid or due to higher utilisation or destruction of this vitamin for some abnormal metabolic functions necessary for the induction of polyploidy by this alkaloid.

The results of both the tables apparently indicate that the above lower value is due to decreased synthesis but when the data of Table I are carefully analysed it is observed that the nicotinic acid content of the untreated seeds gradually increases with the period of germination whereas in case of colchicine-treated seeds the value after the first 24 hours germination suddenly falls below the amount present in the ungerminated diploid seeds and this is interpreted to show that colchicine possibly brings about some changes in the metabolic functions in the seeds for which the need for nicotinic acid is increased and thus a part of it already stored in the cotyledon is destroyed but this increased rate of destruction or utilisation of nicotinic acid cannot even then surpass the rate of it biosynthesis which even under colchicine treatment also seems to proceed in the normal manner as is evident from the gradual increase of the nicotinic acid content after the above decreased value of the first day's germination and also from the attainment of the peak level at a certain period of germination in a manner similar to the untreated seeds.

It is further revealed from the tables that the difference between the nicotinic acid values of colchicine-treated and-untreated seeds as germinated in ammonium sulphate (Table II) is definitely greater than that between the corresponding values of water-germinated seeds (Table I) and this suggests that colchicine not only enhances the utilisation or destruction of nicotinic acid as discussed above but also retards the rate of its synthesis when this process proceeds directly from the inorganic nitrogenous compound—ammonium sulphate—as used for germination.

With the present state of knowledge it is very difficult to predict at what stage of mitotic phases the above vitamin plays its role and how its utilisation is influenced during polyploidisation by colchicine but the facts that both nicotinic acid and the plant growth hormone—indole acetic acid—probably owe their origin through the same intermediates and also that the auxin content of some tetraploid plants produced by colchicine treatment is lower than that of the original diploids [Gustafson 1944], Avery and Pottrof [Gustafson, 1944 ; Avery and Pottrof, 1945] lead us to conceive that probably both the auxin and nicotinic acid are so co-related in their metabolic behaviour that they seem to function almost in the same manner during polyploidisation by colchicine. This and other interesting problems of cytochemistry are at present under investigation and the results will be reported in due course.

Summary

The effect of colchicine treatment on the biosynthesis of nicotinic acid during germination of *mung* and pea seeds in tridistilled water and also in agar-agar medium with ammonium sulphate as the external source of nitrogen, has been studied.

The results show that colchicine-treated seeds contain lower amount of nicotinic acid than the untreated ones—the effect being more prominent in case of those seeds which are germinated in ammonium sulphate medium.

The above decreased value of colchicine-treated seeds has been interpreted as partly due to increased utilisation or destruction of the nicotinic acid as is probably required for some abnormal metabolic functions necessary for induction of polyploidy by colchicine and also partly due to retardation of the biosynthetic process of this growth factor under the influence of this alkaloid.

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A COMPARATIVE STUDY OF THE PHYSICO-CHEMICAL CHARACTERS OF THE CASTINGS OF DIFFERENT INSECTS

By J. G. Shrikhande, and A.N. Pathak, Government Agricultural College, Kanpur

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INSECTS like earthworms, termites and ants, especially the former, have been considered to increase soil fertility. Question has often been asked whether earthworms increase soil fertility or just live in greater abundance in fertile soils without contributing to their fertility.

Several attempts have been made to solve this problem. In 1837 Darwin published a paper in which he showed the important part played by worms in the formation of vegetable mould. Further observations on the activity of worms were recorded by Hensen [1877]. It was not till 1881 that the publication of Darwins' earthworm and vegetable mould focussed a greater attention on the subject. Several investigations have since then been made on the part played by earthworms in promoting soil fertility. Russell [1910] indicated by his pot experiments that earthworm had no direct effect on the production of plant food. On the other hand Hopp and Slater [1948] during the course of their study on the effect of earthworms on soil productivity observed that in soil where unfavourable conditions were not eliminated by the addition of manure, lime, or fertilizers or by cultivation of the soil in the original preparation of the seed-bed, the introduction of earthworms improved the vegetation.

The results reported by these workers were obtained by studying only crop yields from the soils carrying an earthworm flora. They apparently did not take into account the various chemical, physico-chemical and biological changes occurring in the soil medium. Shrikhande and Pathak have studied such changes an account of which was published in a brief note in 1948. Since then the authors have investigated the problem in a considerable detail and the results are reported in this communication. Not only the effect of earthworms was studied but that of other insects as well. Such a comparative study has not been reported so far by any of the previous workers. Opportunity was taken of a site where all the three insects were found working simultaneously in the same plot of land in the garden attached to the residential bungalow of the senior author. For the original soil, samples were collected at different places in the plot. Earthworm casts, termite galleries and ant hills were picked up from the centres of activity of these insects. For analysis composite samples were used for the control and insect-acted soils on air-drying. Table I gives the result of hydrochloric acid-extract analysis.

It will be seen from the data in Table I that all the three insects increased the *p*H, the greatest increase being effected by the earthworms. The loss on ignition by the earthworm casts followed by ants and termites is in keeping with their greater

TABLE I

Mineral composition of the HCl-extract

Per cent	Control soil	Earthworm casts	Termite galleries	Ant hills
*p*H	7·30	8·15	7·83	7·51
Moisture	2·68	2·24	2·62	2·66
Loss on ignition	3·29	4·35	3·14	3·94
HCl-insolubles	81·22	81·55	79·10	81·63
Fe_2O_3	3·08	3·80	3·92	3·64
Al_2O_3	6·79	4·65	6·79	7·2
CaO	1·16	1·93	1·01	1·44
MgO	0·58	0·47	0·73	0·44
K_2O	0·59	1·45	0·75	0·67
P_2O_5	0·903	0·139	0·275	0·133

organic matter content as will be seen from results in Table III. CaO content of earthworm casts is highest which has probably increased its *p*H to a maximum. The three soils are richer in K_2O and P_2O_5 with the maximum K_2O in the earthworm casts and P_2O_5 in termite than the control soil.

Table II contains figures for the available plant nutrients in the four soils. Morgan's method [1936] was used for this determination.

TABLE II

Available nutrients presents in the castings

Percentage of M.E.	Control soil	Earthworm casts	Termite galleries	Ant hills
Total exchangeable—				
Bases	14·81	21·51	14·48	16·83
CaO	13·10	19·00	12·30	14·80
MgO	0·025	0·0556	0·0202	0·0153
K_2O	1·68	2·45	2·16	2·01
P_2O_5	0·0023	0·0043	0·0011	0·0040

It will be observed from the data in Table II that termite *Odontoterme* sp. active in this soil did not increase except K_2O the availability of other minerals as reported by certain workers. On the contrary it decreased the available CaO. Similar decrease was recorded by Griffith [1938] in Uganda and by Jaochim and Kandaih [1940] in Ceylon. This decrease in CaO and a corresponding increase in K_2O are in keeping with the smooth and well set nature of clay galleries built by the termite since K_2O helps in the formation of highly dispersed and sticky clay. Earthworms effected the largest increase in the availability of nutrients followed by ants. This increase in available mineral nutrients by earthworm means greater fertility of the soil bestowed by the earthworms.

In Table III are incorporated figures for carbon, nitrogen and organic matter present in the four soils. Organic carbon was determined by Robinson, McLean and Rice William method [1929].

TABLE III

Organic matter content and C/N ratios of the castings

Per cent	Control soil	Earthworm casts	Termite galleries	Ant hills
Carbon	0·536	1·980	0·576	0·880
Nitrogen	0·087	0·192	0·102	0·126
C/N	6·19	10·32	5·63	6·98
Organic matter (Organic carbon × 1·72)	0·922	3·406	0·990	1·513

It may be noted from the data in Table III that organic matter is increased nearly three and half times by the earthworms over the control, the figures being 3·406 per cent, one and a half times that of the ants, the figure being 1·513 per cent with no apparent increase by the termite, the figure being 0·990 per cent. C/N ratio of the earthworm casts though widest of the whole lot was nearest to the standard ratio of 10 : 1.

All the four soil samples were then treated with H_2O_2 to determine the degree of humification which gives an idea of the availability of nitrogen in the organic matter present in these soils. Residual carbon and nitrogen on peroxide treatment are included in Table IV.

TABLE IV

Organic matter and nitrogen content of the castings after oxidation with H_2O_2

Per cent	Control soil	Earthworm casts	Termite galleries	Ant hills
Carbon	0·382	0·828	0·492	0·776
Nitrogen	0·064	0·118	0·082	0·107
C/N	5·90	7·00	5·90	7·20
Organic matter	0·657	1·875	0·846	1·335
Loss of O.M.	0·165	0·831	0·144	0·178
Loss per cent of O.M.	17·80	24·30	14·50	11·70

A perusal of the data in Table IV shows that the loss of organic matter on oxidation with H_2O_2 is greatest in earthworm casts being 24·3 per cent and least in ant hills of the order of 12 per cent. This indicates that the organic matter passing through the ducts of the earthworm undergoes greater decomposition than when attacked by other insects. The narrowing of C/N ratio by H_2O_2 treatment of the earthworm casts suggests that additional non-humic organic carbon was extracted besides present in humus whereas the extraction of both carbon and nitrogen was proportional since the C/N ratios of other three soils remained almost unaffected.

Mineralization of N and CO_2 evolution from the organic matter in these soils gave the following results which are incorporated in Table V.

TABLE V

Nitrifying capacity and CO_2 evolution of the castings

	Control soil	Earthworm casts	Termite galleries	Ant hills
NO_3-N p.p.m.	11·75	19·25	14·00	19·60
CO_2 evolved in mg. from 100 gm. soil after 5 hours	3·30	4·18	3·96	4·18

From the above data it will be noted that the earthworms and ants render available nitrogen almost to the same extent *i.e.* about 19 p.m. followed by termites giving 14·00 p.p.m. of nitric nitrogen, while for the control soil this figure is 11·75 p.p.m. The similarity in nitrification and CO_2 evolution from earthworm casts and ant hills is in keeping with the equivalence in their C/N ratios after peroxide treatment. Similar reasoning applies to control soil and termite galleries. It has been observed by numerous investigators like Blanck and Giesecke [1924], Duserre [1902], Russell [1910] and Romell [1935] that nitrification is more active in worm inhabited than in other soils. This phenomenon has been severally attributed to increased soil aeration by Blanck and Giesecke [1924], to the alkaline fluids in the digestive tracts of the worms by Duserre [1902], to the decomposition of the bodies of dead earthworms by Russell [1910] and to a higher nitrogen level where a predominantly fungal population is controlled by faunal feeding by Romell [1935].

There is little information concerning the changes in soil microflora, which may take place in the digestive tract of an earthworm or insect. Gordon [1950] observed that nitrifying bacteria do not undergo any important increase or decrease while passing through the earthworm. But from the increase of the nitrifying capacity of these worms-and insects-acted soil, it may be inferred that the number of the nitrifying bacteria might not have increased, but their activity is increased due to the favourable physical conditions and increased available nutrients for their action. Termites and ants, though widely different in life habit to earthworm, also increased the nitrifying power of the soil.

CO_2 evolution further suggests that the bacterial activity in earthworm casts and ant hills is highest followed by termite and the control soil. Taking nitrification and CO_2 evolution as an index of soil fertility, earthworms help most in increasing the fertility of the soil followed by ants and termites. Similar beneficial action by earthworms and ants has been reported by Hopp and Slater [1948].

In order to see how the physical condition of the soil is affected by insects, these soil samples were separated into mechanical fractions by the standard International Method. Results are incorporated in Table VI.

TABLE VI

Mechanical composition of the castings

Percentage of fractions	Control soil	Earthworm casts	Termite galleries	Ant hills
Coarse sand	1·05	0·75	0·73	2·05
Fine sand	53·34	52·85	46·83	48·92
Silt	20·60	18·10	17·50	20·00
Clay	25·00	27·50	32·50	27·50

From the data in Table VI it is seen that there is not much difference in the mechanical fractions of the soils acted upon by these insects except in the finer fractions of termite soil. Earthworm as such ingest the soil and organic matter while the termites use only the finer fractions for making their nests. Their contribution to water stable aggregates is given below in Table VII. Water stable aggregates were determined by the Method of Basu and Sirur [1943].

TABLE VII

Water-stable aggregate of the castings

Per cent	Control soil	Earthworm casts	Termite galleries	Ant hills
A. Clay from mechanical analysis	25·00	27·50	32·50	27·50
B. Clay dispersed in water	15·30	13·16	16·88	15·00
C. Clay in aggregate form	9·70	13·34	15·62	12·50
D. Per cent of clay aggregate greater than 0·002 m.m.	38·80	52·10	48·00	49·00
E. Silt from mechanical analysis	20·60	18·10	17·50	20·00
F. Silt sized particles dispersed	28·31	25·27	31·07	31·56
G. Silt sized particles in aggregate form	1·99	7·17	2·05	0·94

Results in Table VII show that the aggregation of clay particles is affected most by earthworm being 52·1 per cent, followed by ants and termites being 49 and 48 per cent respectively, as compared to 38 per cent in control soil. This clearly demonstrates that earthworm and other insects help in aggregate formation. While passing through the worms, the soil gets mixed with the intestinal juices which help in aggregation of the soil particles. The saliva of the termites gets mixed with the soil while they build their nests which aids in aggregate formation, like-wise ants also help in aggregate formation. During the decomposition of organic matter, as pointed out by Shrikhande [1933, 1 and 2], mucus is produced. Earthworm casts containing greater amount of organic matter on decomposition will produce greater amount of mucus. The high *p*H of earthworm casts is also conducive to such mucus formation. Greater aggregation in earthworm casts may thus be attributed to the formation of greater amount of mucus.

The lowest value of silt fraction (F) in Table VII for earthworm casts suggest that particles smaller than 0·02 m.m. which apparently include both clay and silt have aggregated to produce larger particles. This point is supported by a proportional decrease in the value of (G) which denotes particles forming aggregates larger than silt. In other words earthworm helped most in aggregate formation from the smaller particles as compared to other insects.

It is interesting to note that the percentage of silt found by dispersion in distilled water (F) is more than what has been found by the International Method of mechanical analysis (E). If the aggregates formed from clay (C) would have been of the size of silt and the silt found by mechanical analysis (E) would not have formed aggregates greater than 0·02 m.m., then the particles of size between 0·02 to 0·002 m.m. found by dispersion in distilled water (F) should have been equal to the silt percentage found by mechanical analysis (E) plus the undispersed portion of clay (C) by distilled water. But the total of (C+E) is greater than (F). This means that some portion of the soil fraction lesser than the silt particle has aggregated to form an aggregate larger than 0·02 m.m (G).

Attempts were then made to characterise the properties of these soils by their single value constants. The results are incorporated in Table VIII.

TABLE VIII

Single value constants of the castings

Per cent	Control soil	Earthworms casts	Termite galleries	Ant hills
Moisture equivalent*	25·6	29·4	24·0	22·5
Water holding capacity	44·3	55·5	51·6	46·0
Sticky point moisture	23·5	23·9	22·6	22·7

* By Bouyocos method [1929]

It may be seen from the results in Table VIII that moisture equivalent of earthworm casts has increased while that of termite and ant hill decreased as compared to the control soil : the values for control soil, earthworm casts, termite and ant hills being 25·6, 29·4, 24·0 and 22·5 per cent respectively. These values are important in-as-much as they give a rapid index of the texture. From the figures for W.H.C. it can be said that earthworm cast has got capacity to retain greater moisture than any of the soils studied. Of course, the W.H.C. of termite has also increased over the control soil due to its high clay content.

Summary

A comparative study of the simultaneous activity of earthworms, termites and ants on soil fertility has been made with the following effect on the chemical, biological and physical properties of the soil :

The mineral composition of the HCl-extract showed that the plant nutrients were greater in the three soils than in the control one.

Earthworms increased the availability of plant nutrients to a greater extent than the other insects studied.

The three insect-acted soils were richer in carbon and nitrogen than the control soil, earthworm being the richest with a C/N ratio of 10. Earthworms also appear to decompose organic matter more than the other insects.

The three soils produced more nitrate than the control soil ; earthworm casts and ant hills giving the maximum.

Mechanical fractions of the four soils were more or less of the same order with the exception of termite galleries which increased in clay content.

Insect-acted soils produced larger aggregation than in the control, earthworms producing the maximum aggregation.

Insect activity thus brings about a general improvement of the soil in respect of texture, availability of plant nutrients and biological activity which favourably affect soil fertility.

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ASSESSMENT OF LOSSES CAUSED BY PLANT DISEASES

By R. S. Vasudeva, D.Sc. (Lond.), Ph.D. (Lond.), D. I. C., F. N. I., Head of Division and M. L. Gattani, M. Sc., Ph. D. (Minn.), Assistant Plant Pathologist, Division of Mycology and Plant Pathology, Indian Agricultural Research Institute, New Delhi

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In order to determine the economic importance of a disease and to have a clear conception of the susceptibility or resistance of a crop variety to it, the losses caused by the disease must be assessed. By measuring the losses due to plant diseases in a country, we can get an idea of the relation of weather to the growth and spread of the diseases as well as known whether a disease has been on an increase or a decrease during a particular period. This information is essential for successfully controlling plant disease in an economical and effective way. It is, therefore, essential that the assessment of losses due to plant diseases precedes their control. The estimate of losses due to plant diseases can only be made if comparative figure are available. The only reliable figures available are from the United States Department of Agriculture published by the Bureau of Plant Industry. The losses in yield caused by any disease are recorded for the individual States and for the whole of the U. S. A. The average losses during 1930-39 caused in the U. S. A. by plant diseases in 12 different groups which are also important in India, vary from 6-20 per cent, lowest being in grapes, and the highest in potatoes. The average loss in wheat, maize, cotton and tomato is 10, 12, 16·3 and 16·4 per cent respectively. We have in India, a very large number of diseases, which cause great losses to our crops and the elimination of these diseases is the main feature of the crop improvement work. The losses incurred due to various diseases that attack our crops have not yet been accurately assessed and there are no reliable figures available for this purpose. Some estimates of losses due to diseases however, are available but these are mostly based on personal opinions and guess works of some experienced workers so that accurate surveys yet require to be conducted.

The literature available on the estimates of losses is meagre and different methods have been adopted by different workers. These methods may broadly be grouped into four different types :

(1) Methods involving determination of crop yields under natural or controlled conditions.

(2) Methods involving measurement of the area on which a particular disease has appeared.

(3) Grading and counting.

(4) Miscellaneous

Determination of crop yields under natural or controlled conditions

Under this head, seven different methods for estimating losses due to different diseases have been employed :

Greenhouse method : Under controlled conditions of greenhouse this method has been utilized for the determination of damage caused by rust of definite intensity acting over a definite period in the life of a plant.

Method involving artificial removal of foliage : The diseases causing leaf-spots reduce the photo-synthetic area of the affected parts and an idea of the losses foliar diseases might, therefore, be gained by artificially removing the leaves at different stages in the development of host plant and determining its effect on yield. This method can be conveniently used for assessing losses due to species of *Helminthosporium* causing leaf-spots, *Phytophthora infestans*, etc.

Yield comparison method : In localities where a disease has been severe for a number of years, this method has been used to assess the losses caused by that disease. It involves the comparison of average crop yields for a series of disease-free years with yields during years of disease severity ; other factors being as comparable as possible, the differences in yields in favour of disease-free years may serve as an index of the amount of loss caused by the disease. This method could be used with advantage in this country for determining the losses due to red-rot of sugarcane, late blight of potatoes and wheat rust which are particularly severe during certain years. The method by itself obviously has limited value, but it appears to be of considerable importance in serving to confirm the results obtained by other methods.

Comparison of the yields of resistant and susceptible varieties. This method has been used in America for determining the losses due to bacterial blight of cotton and the black rust of cereals. In Russia it has been used for assessing losses due to brown rust.

If two selected cereal varieties, one susceptible to rust and the other resistant to it, are found as groups to produce approximately equal yields under rust-free conditions, while the yield in the resistant group is advantageous when the two groups are exposed to rust, the difference in yield may be taken as a measure of the loss sustained in the susceptible variety as a result of the rust attack. The reliability of this procedure is correlated with the number of varieties constituting the group, the quality of their yields in the absence of rusts and the correlation between rust intensity and the yield difference. Instead of grouping the varieties, they may be arranged in a progressive series begininng from the variety of highest yield to that of the lowest one under the rust attack. If the disease is then found to be inversely correlated with the yield of each variety, the relationship between the rust increase and the yield decrease is a measure of the loss caused by rust, its reliability being determined by the height of correlation.

Comparison of yields with decrease of infection in selection of vareties or groups of lines from segregating hybrid families : This method is an improvement on the previous one and has been used in Russia and the U. S. A. for assessing losses due to leaf and stem rusts. In this method, it is assumed that a disease-resistant selection from a disease susceptible variety differs little from the parent variety except

in disease reaction, and that a comparison of the yields with disease intensity in the two cases will give a true picture of the effect of known intensity of the disease on yield. Secondly, it is assumed that a group of disease-resistant lines from a resistant susceptible cross differs from a group of susceptible lines of the same cross on an average, mainly in disease resistance. The larger the number of such lines used, the greater the probability that this will be true and that there will be a high correlation between disease differences and yield differences.

Comparison of yields from plots protected with fungicides with yields from unprotected plots: This method can obviously be used for the estimation of losses due to diseases which could be controlled by fungicidal treatments and on the basis of yield, conclusions can be drawn. A modification of this method by artificially inoculating the unprotected plots and finding out disease intensity and yield has been used with advantage by some investigators.

Comparison of anticipated with actual yields: The comparison of expected yields with the actual yields after making due allowance for the various factors which have depressed the yields, is a means of estimating the relationship between the disease and the crop loss. This method of comparing theoretical and actual yields has some significance when porperly used with adequate understanding of the factors involved.

Measurement of area on which disease has appeared

This method of assessing the losses is applicable to that group of diseases in which the plants completely succumb to the attack of the pathogen. This method has been successfully employed in the case of root-rot of cotton in India, wilt diseases due to *Fusaria*, etc. The area of the patch of wilted plants can be measured and the loss due to the crop occupying a particular area determined. As in some of the root-rots and wilt diseases, the disease progresses slowly from a patch in a concentric way, by mapping out the areas the rate of progress of the diseases can also be estimated.

Method involving grading and counting

This method involves sampling of the individual plants or plant parts and has been successfully used in England for the estimation of losses due to late blight of potatoes, apple-scab and for wheat rust in Russia. According to Ruzinov the best means of getting reliable results correlating rust severity with yields under field conditions is to select and compare individual plants from the same field that differ in rust attack.

MISCELLANEOUS

The historical method.—This method refers to comparison of yields before and after some fundamental change has occurred in the culture or environment of the crop so as to substantially affect its pathology, such as widespread application of control measures, or the general invasion of a crop by a formerly unknown or unimportant disease. Losses have been calculated by the application of this principle

in the case of sugarcane mosaic in Louisiana where, as a result of introduction of mosaic resistant variety of cane, the sugarcane production was raised 40 times. The method can be used in this country for determining the losses due to red-rot, as a number of varieties of sugarcane which are susceptible to red-rot are being replaced by resistant ones.

Questionnaire method.—This method can be usefully employed for survey with a view to assessing losses due to plant diseases by summarizing and cautiously interpreting the information received from different sources.

No one method for determining crop losses due to diseases can be preferred over others. Each method has its advantages and its limitations and it can be used under certain circumstances, where others cannot. Experience has shown that combination of two or more methods is more reliable than one. The greater the number of methods that can be employed to obtain evidence on this question, the greater the reliability of the results.

We in India have meagre evidence on the actual losses caused by different plant diseases, as little systematic work has been taken up in this direction. This aspect of the question is extremely important from the point of view of application of control measures, and requires serious attention. With this object in view work on the methods of assessment of losses due to wheat rusts, late blight of potatoes and sugarcane smut was taken up in this Division in 1947-48.

REVIEWS

RURAL BARODA

Introduction by Sir Manilal B. Nanavati

(*Published by the Indian Society of Agricultural Economics, Esplanade Mansions, Fort, Bombay, Rural Life series 1949, pp. 119, Price Rs. 5*)

FOLLOWING the suggestion of the Late League of Nations for a study of rural life in Europe, the Indian Society of Agricultural Economics, under the able leadership of Sir Manilal Nanavati, initiated a similar study of Indian rural condition. The first outcome of it was Rural Problems in Madras [1947],—a monograph of 545 pages published by the Madras Government and reviewed in the Indian Farming [Septmber, 1949]. This one is second in the series and within its small compass it presents a wealth of information recounting the activities and achievements of a foremost Indian State having the rare fortune of an illustrious ruler in the late Maharaja Sayajirao III whose outstanding contribution towards the renaissance of India and uplift of the people in his charge will ever remain emblazoned in India's chequered history.

The only lacuna in the book is that it lacks a map and an index, – a defect in many of the Society's fine publications.

The data relate up to 1945.

The ever increasing preponderance of agriculture (with 64·4 per cent actual agricultural population as compared to 51·9 per cent in 1891) marks the feature of this state despite increase in industry and urbanisation. A redeeming feature however is that 85·7 per cent of the agriculturists own their own land under *ryotwari* tenure paying rent direct to government; and 76 per cent of *khatedars* (registered holders) cultivate their own lands, having average holding of 18·16 bighas (one bigha = 10/17 acres). Only 20 per cent of *khatedars* (owning 25 to 100 bighas) consisting of *anavils* (a sect of brahmans), *patidars*, *kunbis* and a few *banias* are prosperous and able to spend on land improvement, and the rest have a hard lot. Since the World War II land transfer has taken a favourable turn from non-agriculturists to agriculturists.

The Co-operative Societies for consolidation of holdings were 2 in 1924-25 and 71 in 1941-42; but they did little useful work. The Co-operative movement initiated in 1904 covers wide field (1,487 societies in 1944-45) with sound finance.

An experiment on co-operative, collective and inter-related farming is in progress under Indian Council of Agricultural Research grant.

The 'Grow More Food Campaign' has added 5 lakh bighas to food crops, and the 'State ceased to be a deficit area' almost in all food crops except rice. The area cropped more than once is however 166,181 out of 5,512,962 bighas or about 3 per cent.

The agricultural improvements with first phase from 1887 to 1909 covered agricultural education, agricultural farms, agricultural banks, introduction of improved crops, manures, implements, etc. The second phase (1909 to 1927) marked the creation of a separate Agricultural Department with a whole time Director ; and the third phase brought the State in close association with I. C. A. R., I. C. C. C., I. S. A. E., etc. The agricultural budget now amounts to 12 lakhs as compared to 1·3 lakhs in 1931-32. The prospect of potential gain to the cultivator is estimated at 1·87 crores.

The industrial structure is broad based and dispersed affording employment to rural areas. The subsidiary industries largely forming complement to agriculture include dairying and dairy products, poultry, spinning and handloom, eri silk, cotton ginning, rope making, wood carving, paddy-husking, leather, metal, lacquer, etc.

The other points of note are :

(i) As far back as 1896 free and compulsory education was introduced in Amreli and extended to the whole state in 1906-07 on the occasion of the Silver Jubilee of the Gaikward. The village school forms the centre of all benificial activities.

(ii) His Highness also established libraries so that every village might have a free library or at least a free Reading Room and now 82·6 per cent of the population are enjoying these facilities with 1,368 village libraries and 72 district libraries. There are also mobile outfits having in all 345 wooden boxes each with 15 to 30 books.

(iii) There are 13 village water works whereas Bhadran, — a place with 6,000 souls boasts of roads, water works with house-connections, a town hall, a clock tower, a high school, several primary schools for boys and girls, an agricultural bank besides other amenities and institutions.

(iv) In medical relief Baroda probably tops all other Indian provinces and States.

(v) The government established Technological Research Institute in 1936 attached to the Sayaji Jubilee Science Institute where there are the Public Health Institute, the Laboratories of the Agricultural and Excise Chemists as well as of the Chemistry Department of Baroda College. Their proximity to each other provides an ideal condition for collaboration which they are fully utilising. Such a useful feature probably exists nowhere in India.

India's past is a grim record of omissions and commissions. Baroda too was no better until His Highness appeared in the scene with God's gift of a brilliant ruler, combining in one the rare qualities of a statesman and patriot, a pioneer and reformer and a man with farsight, imagination, grit and a desire to do. Baroda's work with her merger with India, now extends to a wider field. To India it is welcome though in the State there may be some misgiving and even regret. Whether there is any cause for such apprehension is beside the point. The dye is cast. Baroda's work is there serving as a beacon light. If she could do so much in spite

of many limitations a double responsibility devolves on India not only to do more, but to see that the former's great progress does not find a set-back. It will be sad if our complaisance leads to such an inglorious drift. (I. C.)

RECENT ADVANCES ON FRUIT JUICE PRODUCTION

Edited by V. L. S. Charley

(*Published by the Commonwealth Agricultural Bureaux, Penglais, Aberystwyth, Great Britain, pp. 176, s. 15, net.*)

THIS outstanding publication is an excellent compilation of very useful information of practical importance based on the work conducted on the subject in different parts of the world since 1939, when Technical Bulletin No. 11 on *Fruit Juices and Related Products* by Charley and Harrison, was published by the Imperial Bureau of Horticulture and Plantation Crops.

Chapters I and II deal with a critical account of the amazingly rapid progress which the fruit juice industry made during the World War II and the four years of the post-war period. The authors have elaborately indicated the all-out effort made by every country during the war period to make good the nutritive deficiencies of its population by making available vitaminized fruit juice beverages in order to maintain its morale and productive capacity at the highest possible level in order to meet the war-time requirements of production. Improvements made in the equipment like Fruit Presses and Mills, Juice Storage Tanks, Bottling Machines, etc., have been graphically described keeping in view the shortage of steel, fuel, etc., due to war-time exegencies.

In Chapter III, improved production technique is outlined for tomato juice, apple juice and grape juice, with special reference to (1) the fortification of vitamin C content of apple juice a process which is covered by a Canadian Patent, (2) blends of apple juice with lime, grape fruit, rasberry and (3) the latest Swiss method of enzymic clarification of fruit juices. The use of copper equipment for processing the juices is discouraged.

Chapter IV deals with the latest processing improvements made in the de-aeration and pasteurization equipment used for commercial processing of pure fruit juices. A combined unit of de-aeration and flash pasteurization as developed by A. P. V. Company, London, is described. The latest American processing equipment (Buflorak de-aerator and de-oiler) for citrus juices in which, the juice is simultaneously de-aerated and de-oiled, has been claimed to yield comparatively better products. Progress in the use of electrical energy for pasteurization has been shown to be slow due to economic considerations.

Developments in the methods of concentration of fruit juices have been given in Chapter V in which some latest commercial vacuum concentration plants have been described.

Some interesting observations have been recorded in Chapter VI with regard to citrus essential oil industry.

Chapter VII is of special interest to the manufacturers and consumer of our country as it deals with the methods mainly developed during the war-time for the production of vitaminized fruit syrups from fruits like black current, rose-hip, etc.

Advantages of using fruit juices and syrups are the subject matter of Chapter VIII.

Chapters IX and X are devoted to a critical review and discussion on the nutritive value of fruit juices and the related products, with elaborate analytical data on different kinds of fruits and fruit juices. Some latest interesting observations have been recorded on the fortification of juices with added ascorbic acid.

Chapter XI is a resume of the part played by the pectic anzymes in the clarification of juices and fermented beverages.

Chapter XII gives a brief review of the work done on fruit juice industry in the Commonwealth countries like Australia, Canada, India, New Zealand, Palestine, South Africa, etc.

The publication is considered to be of great practical value for fruit juice preservers, research workers and students interested in Fruit Juice Industry. (G. L.)

PROBLEMS OF ZAMINDARI AND LAND TENURE RE-CONSTRUCTION

Edited by PESHOTAN N. DRIVER

(*Published by Phiroze F. Dinshowfor, New Book Co., Ltd., Hornby Road, Bombay, Rs. 12-8 as., pp. 310*)

PRESENT and future pattern of land system in the country has been accorded a most comprehensive treatment by Prof. Peshoton Nasserwanji Driver in 'Problems of Zamindari and Land Tenure Re-construction in India' (New Book Company, Ltd., Bombay), which provides a first class reading, although at places one feels the author could avoid repetition and improve by being less incisive.

More than hundred pages (out of a total of 310) are devoted to make what is now an accepted plea, viz., abolition of the zamindari system. Obviously, this is more or less of an academic interest but since the future pattern of agricultural organisation will depend greatly on the purpose and objective of land reforms at present, a discussion of the issue is of vital practical importance. Prof. Driver stresses that economic drawbacks of landlordism are not confined to *zamindari* system alone and has challenged the naive assumption that abolition of *zamindari* would or should lead to a system of peasant-proprietorship. As *zamindari* system

cannot be mended by tenancy reforms or progressive taxation, *ryotwari* too has similar features and its substitution for the former does not lead us anywhere.

In both *zamindari* and *ryotwari* systems land is being held by a few leading to a most defective organisation of a very high labour—intensive agriculture, where the actual worker is constantly pushed back to a level—below-subsistence as a labourer without any rights in land or with inferior rights. If in the Uttar Pradesh, a *zamindari* tract, of the total cultivated area less than 15 per cent is cultivated by fifty-six per cent of the total number of cultivators, in Bombay, a *ryotwari* area, fifty per cent of land holders hold less than 10 per cent of cultivated land while a few hundreds with large holdings have between them about 50 per cent of the total. If in North Bihar the land-less form at certain places 70 per cent of the agricultural population, conditions are no better in *ryotwari* Madras, where even in 1931, forty-three per cent of agricultural population comprised of land-less labourers. In the permanently settled area of Bihar according to Dr Radha Kamal Mukerjee there are 725 agricultural labourers for every 25 non-cultivating landlords and tenants. Under temporary settlement in the Uttar Pradesh there are no less than 10 million agricultural workers including those who hold small pieces of land of less than two acres as against a few thousands who hold bulk of the land. Vast man-power remains under-employed with such land distribution either under *zamindari* or *ryotwari* and yet redistribution is no solution as it will simply make the few solvent holdings uneconomic. Productivity per worker remains so low that withdrawal of even substantial numbers from agriculture seldom reduces total output. The case for land reforms is thus based on basic needs of an economy awaiting expansion and progress. It opens with *zamindari* but does not end there.

Prof. Driver's approach to the question of compensation is entirely objective. He warns against abolition without compensation, which is practicable only in the midst of an environment of 'blood and iron' and pleads for a compensation approximating roughly to ten times the present net profits that would be sufficient to guarantee 30 per cent of the present individual incomes. Of the compensation money twenty to fifty per cent may be paid in cash and the balance in bounds. The problems, however, is beset with more than ordinary difficulties and the financial positions of many States today makes even such modest payment doubtful. In a recent issue of the *Reserve Bank Bulletin* [June, 1940] it has been calculated that in the seven States of Madras, Uttar Pradesh, Bihar, Madhya Pradesh, West Bengal, Orissa and Assam, *zamindari* system is proposed to be abolished over an area exceeding 170 million acres of land at a total compensation cost of Rs. 414 crores, i.e., a sum about three times the total public debt of all the former provinces taken together. An opinion has been expressed that payment of the entire or a substantial part of this compensation in cash or in negotiable bonds at the present juncture is impracticable except perhaps in Madras. Hence the main part of compensation will have to be paid in the form of annuities or non-negotiable bonds. Since compensation amount can further be reduced little a further discussion of alternative methods of payment by Prof. Driver would have been more helpful. For instance, one would like to know what the learned author thinks about payment through creation of *ad hoc* securities in favour of state co-operative banks coupled with compulsory

long-term deposits of the compensation money in the co-operatives. A method like this may help in renovating agricultural credit simultaneously with land reforms, dovetailing agricultural economy into a cooperative structure.

Prof. Driver challenges the efficacy of peasant proprietorship to subserve the aims of an expanding economy under the man-power land-resources relationship subsisting at present in the country. In treating the population problem he is still obsessed by a theory which has long been discredited. He is of course not alone in clinging to this error. Nevertheless, this obsession leads him to discard freedom in farming operations and advocate adoption of a socio-cooperative state which in plain words will be an amalgam of regimented monopolistic economy. He has made the assumption that productivity in agriculture can be increased only by bringing the small man into an ever-increasing sphere of large-scale production through collective cooperative farming. He is ever looking so much to Russia, which in his opinion has a record of material progress 'which has probably never been equalled in any other country at any period of its history' that one finds little discussion here of the bases of agricultural progress in other countries. He even finds much in Russian collectivism that is truly cooperative and has taken so much for granted in its favour that the problem of incentives barely presents any hurdles. One still wonders as to why average productivity per acre is one of the lowest in U.S.S.R. Why productivity per man in agriculture under individual farming in the U. S. A. is about four and one-half times as large as in the U. S. S. R. ? Why, again, productivity and out-put throughout the last decade have increased much less in U. S. S. R. than in many countries outside ? Or why is it that *per capita* food supplies in Russia are poorer both in quantity and quality than under a free market economy in North and South America, Oceania, Scandinavia, United Kingdom or even in Central and Western Europe ?

Collective cooperation does not fit in with all stages and types of farming. Prof. Driver does not mention that it is a poorly balanced tripod of which modern technology, mechanized farming and large scale industrialisation form the legs and we in the near future have not enough means to build it. Large capital investment both in industry and agriculture will have to be telescoped in a short period perhaps in a few months, if Prof. Driver is to have his way, to build this slender economy. Where is the capital ? How does he reconcile the present low rate of capital formation in the country to the demands of the socio-cooperative state has remained for the most part unexplained.

Prof. Driver has often been gazing at fields of Ukraine as if to drive inspiration, and asks his countrymen to make a careful study of collectivization in Russia. One hopes that the precept was not meant simply for others and yet one finds that he seldom draws on sources which present Russian economy in its true perspective. One of the latest studies is that of Naum Jasny—*The Socialized Agriculture of the U. S. S. R.* [Stanford University Press, 1949]. Unless we discredit this scientific work as coloured by bourgeois fixation there is no escape from the truth, which Prof. Driver has all along avoided to face, that socialized agriculture in Russia failed to produce either abundantly or cheaply. Not necessarily that it will be same

in India but logically enough one may argue that if similar means are adopted, i.e., if cooperation is forced, results cannot be very much dissimilar.

Russian experience has compelled the communist party of China to retain a rich peasant economy in the People's Republic 'to develop agricultural production, and pave the way for industrialization of new China' (The Agrarian Reform Law Article I). Liu Sheo-Chi, Vice-Chairman, has made it plain that peasant economy will be preserved in the whole stage of New Democracy because unless conditions mature for a wide use of mechanised farming, for organisation of collective farms and for socialist reform of rural areas a rich peasant economy is indispensable for raising output and productivity. It takes long for an economy to mature for such task. Builders of new China, none will deny, have vision. Prof. Driver wants us to run faster than possibly we can if we want to be alive too. Under collective cooperation few occasions will be left for individual workers to make a rational choice between various alternatives in spheres of production or distribution. Action will be predetermined by social needs and welfare criteria but it is very much doubtful if any rational choice can be made when economic calculation is dropped. Prof. Driver disappoints his more serious readers when he ignores this aspect of his socio-cooperative state altogether.

Nevertheless, Prof. Driver's work is very comprehensive and permeated by a sense of realism. One may not agree with his views but one cannot fail to be struck by his clarity, force and lucidity. It is pleasant, stimulating and thought-provoking. (B.S.)

THE MANAGEMENT OF FARM WOODLANDS

Edited by Cedric H. Gruise

(Published by McGraw-Hill International Corporation, 330 West 42nd Street, New York, pp. 356, Price $4-00)

In the second edition of his book 'The management of Farm Woodlands', brought out after ten years, Mr. Gruise has maintained the previous lucid standard, and has incorporated many widely accepted developments in the technique of management of small forest areas. While this book deals directly with the problems of the small farm woodlands of the U. S. A., the general principles enunciated, and the methods suggested, are of universal appeal, and may be tried in any country where similar problem prevails.

In India there are extensive private forests which are not managed under any definite silvicultural principles. This book will be of use to all such proprietors of private forests and *zamindars* who are usually not conversant with higher silvicultural principles. As the book is written in clear and non-technical language, it will appeal to general readers as well. Attempts are being made in Uttar Pradesh, Bihar, West Bengal, Madhya Pradesh and Madras to take over private forests due to their bad management in the past. In Uttar Pradesh and Bihar, the private owners are given an opportunity of managing their own forests before they are taken over. This book will be of immense use to all such owners.

The evil effects of intense grazing on forest lands have been stressed. Grazing assumes a high importance specially in farm woodlands as they are situated near agricultural lands and cattle must necessarily resort to them before proceeding to more distant areas. Most of our private forests suffer from the evil effects of excessive grazing. In India rotational grazing has been tried in some forests. It would have been useful if the author described the general principles of rotational grazing to help the forest owners, who also own stocks of cattle.

The author has included in this edition a description of the modern mechanical equipment such as power saws and the planting machines which are used in the U. S. A. These machines can be used when the area is large and the terrain is favourable. It is doubtful whether many owners of small farm woodlands are in a position to resort to mechanical aid for planting and exploitation. In India under the present conditions it is usually out of the question. This Chapter will be of use only in giving an idea of what is possible with modern equipment, even in the region of forestry. The book will be of use to students in Forestry and Agricultural Colleges as a general study of the modern methods of forests as applied in the United States. Many of our Forest officers will find it useful in refreshing their memory about forest management. (I. B.)

TEACHING AGRICULTURE

By Carsie Hammonds

(*Published by McGraw-Hill Book Co., New York and London, First edition 1950, pp. 353*)

THIS book as mentioned in the preface 'is designed for teachers and prospective teachers of agriculture' and in this an 'effort has been made to provide a background of educational concepts, philosophy and psychology for teaching agriculture'. At the same time, it is not primarily a handbook for teaching devices. But many specific techniques and procedures are suggested ; and principles of both group and individual teaching are discussed. The body is divided into 17 chapters including the introduction. Of this, the first four chapters dilate on the fundamental problems of teaching. In the following three chapters are discussed manupulative abilities, attitudes and supervising practices, while the subsequent seven chapters deal with such organizations as the Future Farmers of America and the different systems of agricultural education obtaining in the U. S. A. The subject matter of the concluding two chapters are connected with the evaluation of student growth and the teaching of agriculture as a profession.

Agriculture is defined as an art, science and as a mode of life, and farming as a vocation. In dealing with the principles of agricultural learning and teaching, the aims and functions of the different aspects of the subject such as vocational and prevocational education, general and college instruction and extension methods are discussed. The cultural, ethical, and economic contributions to the nation are underlined. In planning a course of study to meet the requirements of different communities the major factors by which the teacher should be guided are elaborated.

In a chapter on supervising practices, such aspects of training as farming programme in vocational agriculture, helping boys and young men in deciding on their farming programme and making arrangements for the same, writing project plans, keeping records, summarising, interpreting and using records and supervising farming programme on the farms are elaborately dealt with.

Among the three youth organisations of the U. S. A., Future Farmers of America, New Farmers of America and the 4-H Clubs, the first two are connected with vocational agriculture in public schools, while the remaining one is concerned with Agricultural Extension Service. All these have significant roles in the sphere of agricultural teaching in the U. S. A. as is explained in chapter IX. In the subsequent chapters as already pointed out teaching young and adult Farmers' course as well as Elementary, Prevocational, General, College and Extension teaching of agriculture are reviewed and discussed. The book concludes with a chapter on teaching agriculture as a profession. There is also an index which forms a helpful appendage to the volume.

Agricultural Educationists in India, will incidentally note the similarity in the history of early agricultural education in India with that of the U. S. A. Teaching of agriculture in elementary schools reached its maximum development in the U.S.A. near about 1910-15 while in India it occurred somewhere near the nineteen thirtees. Yet, in the United States of America, 'Agriculture waned in the elementary schools as it developed in the High Schools, where it had first been taught'. Generally speaking, attempts 'at teaching agriculture in the Elementary Schools have not been successful. Likewise, by the large, the programmes of general or non-vocational agriculture in High Schools have not been successful. They are at present, on the whole weak and inadequate ' (page 297). The situation in our country in these respects is much the same. The reasons given for this state of affairs *viz.* 'teachers untrained in agriculture, many of them with poor attitude towards agriculture, too many subjects to teach, and adherence too strictly to recitations from text books that are not suited to the needs' seem to be equally applicable to our case as well, of course with several other factors.

This publication, in spite of its obvious appeal to American readers is a unique treatise on agricultural teaching. Against a rich background of sound educational concepts, philosophy and psychology, specific techniques for teaching agriculture are suggested covering recent advances in the field. The book will no doubt be found useful in other countries as well ; especially in the case of India when our whole system of agricultural education is in the melting pot. (M.R.P.)

YEAR BOOK OF AGRICULTURAL CO-OPERATION

By P. J. Chinmulgund

(Published by Macmillian and Co. Ltd., London, 21s., pp. 337)

THE Year Book of Agricultural Co-operation for 1950 has kept up its high standard and contains articles written by different experts on co-operation in many lands of both Eastern and Western hemisphere. The book begins with three articles

of a general nature. The first deals with the place of co-operation in national economy. It is interesting to note that 37 per cent of the total population in U. S. S. R. is member of the co-operative movement, whereas the figures for Europe and Asia are 14·3 and 4·2 respectively. It is also seen that the proportion of national retail trade carried by consumers co-operatives has shown a marked increase in different countries as compared with the pre-war figures. It is especially noteworthy that in Denmark this figure has risen from 10 per cent in pre-war years to 25 to 30 per cent in the last year. The current figure for U. S. S. R. is 50 per cent, but as the corresponding figure for pre-war years is not available, it is somewhat difficult to say whether there has been an equally rapid progress. One remark in this article is worth quoting and deserves careful consideration both by co-operators and by Government: 'Co-operation should not be a temporary substitute for State socialism, as it is held to be in a number of communities to-day ; rather, State intervention, notably in agricultural distribution, should be a temporary substitute for co-operation'.

The chapter 'The taxation of co-operatives' by Joan Tracey shows that the practice and law in regard to taxation of co-operative profits is not uniform in different countries. Many countries grant complete exemption from taxation for a given number of years, while in some countries, certain types of co-operative societies enjoy no exemption at all. In this connection, it may be mentioned that the qusstion of exempting co-operative housing societies from income tax has been engaging the attention of co-operators in Bombay, and the result of their efforts in this direction will be watched with considerable interest.

Enid M. Owen has given a very instructive survey of the co-operative distribution and manufacture of agricultural machinery. It is worth noting here that, in Great Britain, although the sales account for the greater part of the turnover much more time in actual man hours is spent on the servicing installation and repair of machinery. It may, therefore, be said that co-operative organizations undertaking distribution of agricultural machinery should, side by side, provide repair and servicing facilities, if they are to satisfy the needs of agriculturists in India where in a greater part of the country servicing and repair facilities are non-existent.

A very interesting feature of co-operation in France is the rapid growth of the Unions and Federations of the co-operative societies since after the war. Every branch of agricultural co-operation has a National Union and a National Federation, and these bodies make an effective contribution to the improvement of agricultural production and of the outlets of agricultural produce. It is obvious that we cannot have such a system in India in view of the fact that conditions vary radically from State to State, but it should be possible for each State to have apex federal institutions covering different types of co-operative activity, so that the linking of primary societies and also making available a wider market to primary, marketing or producers societies can be brought about.

Coming to South Eastern Europe, we find that great efforts are being made in Jugoslavia to organize the country on a basis of co-operative farming, and it is expected that by the end of 1951, half the farms of Jugoslavia will be merged in

co-operatives. As Jugoslavia is predominantly a country of conservative peasants, it may be worth-while for India to watch the progress in this direction and see how far it succeeds ; but it may also be pointed out that the success of this plan in Jugoslavia will be made easier by loans from America and England which will make agricultural machinery readily available.

A remarkable feature of the co-operative development in Japan is the important place held by multi-purpose and sericultural societies. There are 13,301 of the farmer and 111 of the later types of societies. The difficulty of co-operative societies in Japan seems to be that Government policies are not conducive to the independent existence of agricultural co-operative societies and it is feared that the economic stabilization programme is likely to reduce farm households to poverty and that premature decontrol of trade will give financial trade and industrial interests an opportunity to infiltrate the country and exploit the farmer. This point is of great interest to us, since in India also the co-operative movement has received great impetus due to control of trade, especially in foodgrains and the emphasis laid by various States that controlled distribution should, as far as possible, be carried on by co-operative organizations premature decontrol of trade, is almost certain to have an adverse effect on the co-operative movement, more particularly on consumers co-operation. It is, therefore, necessary that co-operators plan from now on consolidation and stabilization of the movement, so that it will be able to stand its ground even when decontrol comes about and a free economy prevails.

It is seen that in the United States of America, the business of farmers' marketing and purchasing associations has shown an increase of 21·3 per cent in 1947-48 as against that in 1946-47. During the same years, the membership of these associations has gone up by 8·4 per cent. It is pointed out that the real test of farm co-operatives will come if the prices of agricultural produce continue to go down ; but it is expected that even then the co-operatives will maintain their strength as they are in a much stronger position than at the beginning of the war. In fact, it has been mentioned that the adjustments which co-operatives have been forced to make because of changed economic conditions have made them more efficient.

It is surprizing to find that India finds no place in this Year Book. The reason for this is not known. It is hoped that in the next Year Book a separate chapter will be devoted to India, as was done in the earlier editions of this Year Book.

Separate sections are devoted to new books, surveys and reports and to a select bibliography of Co-operation. From the bibliography it is seen that as far as India is concerned, some publications in Bombay and Assam are noted. It is not clear whether other States have not brought out any important publications during the year under review. (P.J.C.)

ECONOMICS WITH APPLICATION TO AGRICULTURE

By E. F. Dummeier, R. B. Heflebower and T. Norman

(*Published by McGraw-Hill Book Co., N. Y., 718, 3rd edition, pp. 6×9, 1950. $5·00*)

THIS is the third and thoroughly revised edition of a valuable and well-established book in Agricultural Economics. The first edition came out in 1934 under the joint authorship of E. F. Dummeier, professor of Economics, the State College of

Washington, and R. B. Heflebower, professor of Economics, Northwestern University. Because of the deceas of Dr Dummeier, since then, this new edition has been revised by Dr Heflebower and Dr T. Norman, formerly Head Economists, Food Distribution Administration of the United States Department of Agriculture. The short period within which the third edition has to be brought out is an indication of its utility and popularity.

Agricultural Economics has been regarded as a science comparatively recently. Fifty years ago most people would have classified it as *art*; whereas to-day most people would admit the well-established position of agricultural Economics among social sciences. Because of its infancy, the growth has been rapid. Not only the knowledge of statistical methods had been very useful to approach many of these problems more scientifically, but the political and economic developments in the last decade had been such that they had stimulated a great deal of attention and thought from leading economists. The result of all this was that a book written just ten years ago was fast becoming out of date and fit for a museum! Consequently the only way to revitalize it and put it back to the modern shelves for constant reference and use is to revise it thoroughly.

The authors have succeeded admirably in this task. Only a careful study of the book will reveal the pain and care that has gone into the revision of the book. Since this book first appeared many more books have been published on Agricultural economics and allied subjects. The references suggested for further reading at the end of each chapter of the first edition has, therefore, become out of date. Similarly the statistical information in the earlier volume have become mere historical records and not good enough to be used as illustrative materials. Hence the authors have completely revised references suggested for further reading and have brought statistical data up-to-date. A number of graphs and charts have also been revised on the light of new knowledge available since the first edition appeared. Questions and topics of discussion have also been changd. New examples and illustrations are used to bring it with the memory of man. For example in the chapter on the Index number of Prices the earlier edition gave an illustration utilizing 1930 prices with 1929 as base; whereas in the new one, 1946 prices are used with 1939 as base. Such changes help greatly in revitalizing an old edition.

The attempt of the authors to bring the book in line with the literature in the field is noticeable particularly in the chapters on 'Production and value theory on Money and on Business cycles'. The new emphasis in certain sub-sections are most welcome. The revolution in agriculture is recognized and the place of soil conservation in the American economic development is stressed. The discussion on costs is more balanced. This will be more valuable to agricultural economists in our country especially because of the importance of this topic to current problems, of food deficit and price control.

One need not read many pages to find out that the new third edition makes easier reading and in every way more attractive, giving proper emphasis on many of the branches of Agricultural Economics. Only one of the branches, namely Farm Management has not been given its full recognition. This book will be an

excellent reference book and should find a place in all libraries. It will benefit students, teachers and those interested in economic problems of agriculture in our land. Although the book was written for American conditions and with American background, the essential principles discussed therein will be found useful. (H.S.A.)

COCONUT CULTIVATION

By C. M. John

(*Published by the Indian Central Coconut Committee, Ernakulam, 1950; As. 10*)

THIS publication is a useful handbook of directions for coconut growers. The author has brought to bear his experience of coconut cultivation in bringing together the information available on the subject. It deals with the importance of coconut in the South where it grows extensively and is the mainstay of a flourishing industry of copra, coconut oil, oil cake and fibre—all of very great commercial importance. India is the third largest coconut growing country in the world with 1·5 million acres producing 3,000 million nuts annually.

The various aspects of cultural operations for growing coconut are described lucidly and the hints given are based on the results of improved methods as followed at various experimental stations. Rightly, particular attention is invited to the selection of the mother palms from which seed nuts are to be taken for raising seedlings. The important characters to be borne in mind for this purpose are given on page 9. Precisely, trees yielding over 100 nuts per year are recommended. They should also be rich and regular annual bearers.

The selection of seed nuts is the next step of great importance. They should be harvested when fully ripe, preferably when they are 12 months old. Equally important is the selection of seedlings in the nursery. Points for consideration are, the health, vigour, girth and intensity of the roots of seedlings. It is significant that the seedlings selected on the basis of these considerations have actually shown better growth and given higher yields.

The age of seedlings is a matter of opinion in different localities. In the Samalkota area, *ryots* prefer two to three years old seedlings while the Department of Agriculture sells one-year old plants. It is however advisable that seedlings bearing roots should be preferred to reduce mortality. In this connection the author should have made reference to the experimental work in progress at Nileshwar and the results obtained in hybridization. There, a correlation has been found between early splitting of the leaflets in a seedling and its bearing capacity.

Suggestions for manuring of coconut plants are valuable for its scope for application in different localities. The sugges tion regarding green manuring with wild sunn hemp (*Crotolaria striata* D. C.) giving the best results is noticeable. The Department of Agriculture is recommending it along with the use of husk and leaves of coconut as the effect lasts for many years.

The chapters on the control of fungal diseases and insect and other pests will be found very instructive for the protection of plants both in regard to preventive and

remedial measures. The publication can be recommended both to the cultivators of coconut and the industrialists, on account of the useful information contained in it. (J.C.L.)

AGRICULTURAL REQUISITES IN LATIN AMERICA

(*Published by United Nations Department of Economic Affairs, Lake Success, New York, 1950; $1·25*)

THIS is a report of the Joint ECLA/FAO Working Party. The Joint Working Party submitted report after visiting 'all the countries of Latin America doing research work on the supply situation of agricultural requisites and collecting data for the report. The report analyses the use of agricultural requisites in Latin America and the factors which are retarding the increased production of food in the region'.

Chapter I studies the physiographic, sociological, economic and financial factors affecting good production.

In Chapters II to VII, the material factors influencing food production in Latin America are discussed. The problems have been discussed on a regional basis and attention has also been paid to particular situations in individual countries. In no case could a quantitative evaluation of future needs be made, due, among other causes, to the lack of statistics to evaluate those needs. Such a quantitative evolution of future needs is equally necessary for India if our plans of food production are to be put on a sound basis. Another observation of interest to India is that 'agriculture should be given the place it deserves in the total economy of the country' and that 'the immediate need is for action'. 'Increased supplies of fertilizers, farm machinery, pesticides and fungicides must flow into the countries where research and extension work are organized, education services established and health conditions improved. The inter-relationship of these elements constitutes the main difficulty and the challenge which Governments now confront.' The success depends on the ability of Government to meet this challenge.

Regarding the principal impediments to the greater utilization of agricultural requisites mention has been made of:

(*a*) 'Inadequate agricultural extension services';

(*b*) 'Lack of technical education';

(*c*) 'Inadequate research into the types of agricultural requisites needed for specific conditions.' 'Not enough is known yet regarding the fertilizer needs of different soils, the adoption of pesticides to local pests and diseases, or the kinds of machinery required for the various types of work in different localities';

(*d*) 'Insufficient credit facilities', both for the purchase of agricultural requisites and for the general fostering of agricultural development. This is true also for fishermen, processors and distributors ;

(*e*) 'The high cost of most requisites to the farmer compared with the prices which he has to pay in industrially more advanced countries' resulting from freights and distribution charges from town to farm ;

(*f*) 'Shortage of foreign exchange, particularly of dollars' ;

(*g*) 'Low yields per unit-area, which are not only partly responsible for the poverty of farmers but which often make the use of modern requisites actually uneconomic' ;

(*h*) 'The smallness of the farms or operating units in many parts of the region which restricts chiefly to the use of power-machinery pools, such as are being used in a number of countries' ;

(*i*) 'Low rural incomes and comparative abundance of labour due principally to lack of alternative employment opportunities, which would be provided by industrialization. This is an impediment chiefly to the use of machinery, which displaces labour' ;

(*j*) 'The poor transport network, particularly the primitive rural roads or tracks'.

'The use of machinery, fertilizers and pesticides remains almost negligible per unit of crop area when compared with other regions.' 'Many Governments in Latin America have recently established farm machinery pools, and government agencies are responsible for a large proportion of the importation of power machinery in many countries.' The report also discusses the production of agricultural requisites within the country, losses through pests and diseases while storing and possiblities for expansion of cultivated areas and more intensive farming. Regarding 'land reclamation and colonization programmes' it states that these require large capital investments. Finance presents the main obstacle to bringing new areas under cultivation and this raises the question whether such money could not —often be expended to greater effect in programmes for raising the yield on land already farmed. Improvement of fisheries is also discussed. It is pointed out that 135,000 fishermen of this region land less fish than the 6,300 fishermen of Iceland, and suggestions have been made for improving the position. The Joint Working Party point out in their report that 'having started its enquiries upon the assumption that shortages of farm requisites are the major impediment to agricultural improvement in the region, they have been driven inexorably to the conclusion that, in most cases, the chief obstacles are quite otherwise'. Consequently the Joint Working Party have given first place to their suggestions on government services to agriculture and other general topics, and second place to the suggestions on individual requisites.

The report contains very valuable information and is sure to be useful to all interested in the improvement of Indian Agriculture. Valuable technical information is also available in the report. (J.N.M.)

THE SUGAR INDUSTRY (1950) ANNUAL

Edited by M. P. GANDHI, M.A., F.R.E.S., F.S.S., J.P.

(*Published by Gandhi & Co., Jan Mansion, Sir Pherozshah Mehta Road, Fort, Bombay, pp. 350, Price Rs. 6*)

THE long awaited 1950 Annual of the Sugar Industry which is the 15th Annual number of this important *Vade Mecum* has at last been published in June, 1951. Shri Gandhi has ascribed the unusual delay in its publication to the constant changes in the Government's new policy regarding sugar which was fluctuating greatly in the initial period and therefore he felt that it would not be useful to the readers, if the *Annual* was presented when the policy had not steadied itself. This explanation is satisfactory and will be appreciated by all readers.

Shri M. P. Gandhi is to be congratulated by all interested in the production and development of the second-largest Industry in India for presenting annually 'the most indispensable and authoritative annual reference book for the Indian Sugar Industry'.

In the present volume there has been some reorientation of the method of presentation of facts, statistics and comments relating to the Sugar Industry and unlike the past Annuals the present one is divided into Chapters, and detailed contents, both of the matter as well as of tables, have been provided. This innovation is very helpful and will facilitate quick reference.

In this volume, Shri Gandhi admits that the policy of decontrol of sugar after building up a minimum reserve has met with tremendous success and he recommends that it should be extended to other commodities, such as textiles, other manufactured products and even food grains, with a view to create attractive conditions for enhanced production and consequently abolition of shortages and elimination of black-marketing. He states that 'Food problem apart, the Hon'ble Shri K. M. Munshi deserves a high word of praise for his foresight in launching the new sugar policy, amending it with resourcefulness and carrying it successfully through'.

The *Annual* has been well presented, attractively printed and priced low and will undoubtedly be extended the reception it deserves from all its readers. (R.D.B.)

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(March, 1951)

Instructions to Authors

Articles intended for *The Indian Journal of Agricultural Science* should be accompanied by short popular abstracts of about 330 words each.

In the case of botanical and zoological names the International Rules of Botanical Nomenclature and the International Rules of Zoological Nomenclature should be followed.

Reference to literature, arranged, alphabetically according to author's names, should be placed at the end of the article, the various reference to each author being arranged chronologically. Each reference should contain the name of the author (with initials), the year of publication, title of the article, the abbreviated title of the publication, volume and page. In the text, the reference should be indicated by the author's name, followed by the year of publication enclosed in brackets; when the author's name occurs in the text, the year of publication only need be given in brackets. If the reference is made to several articles published by one author in a single year these should be numbered in sequence and the number quoted after year both in the text and the collected references.

If a paper has not been seen in original it is safe to state 'original not seen'. Sources of information should be specifically acknowledged.

As the *format* of the journal has been standardized, the size adopted being crown quarto (about $7\frac{1}{2}$ in. $\times 9\frac{5}{8}$ in. cut), no text figure, when printed should exceed $4\frac{1}{2}$ in. $\times 5$ in. Figures for plates should be so planned as to fill a crown quarto page, the maximum space available for figures being $5\frac{1}{2}$ in. $\times 8$ in. exclusive of that for letter press printing.

Copies of detailed instructions can be had from the Secretary, Indian Council of Agricultural Research, New Delhi.